Report to Congress

Unexploded Ordnance Clearance

A Coordinated Approach to Requirements and Technology Development

Humanitarian Demining
(HD)

Explosive Ordnance Disposal
(EOD)

Office of the Under Secretary of Defense
(Acquisition and Technology)

25 March 1997

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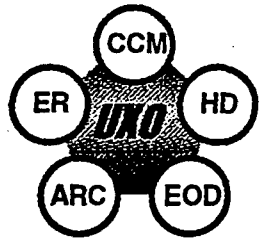
THE JOINT UNEXPLODED ORDNANCE CLEARANCE STEERING GROUP



FOREWORD

Unexploded Ordnance (UXO) detection and clearance are difficult and complex technical problems. UXO includes Countermine operations -- detecting and dealing with landmines in a combat environment and Explosive Ordnance Disposal -- detecting and neutralizing unexploded ordnance in peacetime, in combat operations and in operations other than war. It also includes Humanitarian Demining -- the detection and neutralization of landmines scattered indiscriminately by warring parties in many nations of the world as well as the clearance of active ranges in the military services and the environmental remediation of Formerly Used Defense Sites (FUDS).

This study relates the actions by the Department of Defense to develop a requirements based process to better understand where we must invest to provide critical operational capabilities for the uniformed services, support humanitarian demining programs and support national priorities to clean up the environment. This knowledge will help us invest our limited resources wisely to ensure the highest payoff and to share technologies across the uniformed services and DoD agencies with mission responsibilities in these important areas.

The technology to detect and dispose of unexploded ordnance is the common denominator for all five UXO mission areas. Technology solutions are now potentially available to us that were not available as recently as a few years ago. This study discusses those technologies and how we can apply them to solve these problems.

This is an important issue for the Department of Defense and requires continuing attention. This study proposes a structure that will enable us to maintain visibility across the entire department of the technology investigations underway so that we may better leverage our efforts and efficiently transfer technology to support solutions in all five mission areas. We have also developed an effective means to interact with other government agencies and interested parties outside the DoD who can support these important efforts. The Joint UXO Coordination Office (JUXOCO) will serve as an integrating and coordinating agent in DoD for UXO technology development managers. It will help us manage these programs more effectively.

This study is the product of the collective efforts of the Uniformed Services, the Deputy Under Secretary of Defense for Environmental Security (ES), the Office of the Assistant Secretary of Defense for Special Operations and Low Intensity Conflict (SO/LIC), DoD Director, Strategic and Tactical Systems (S&TS), DoD Director, Test, Systems Engineering and Evaluation (DTSE&E), DoD Director, Research and Engineering, the Defense Advanced Research Projects Agency (DARPA) and the J-8. Representatives from the Department of Energy were also active participants. The results clearly show that we can work together with a common vision to achieve a common purpose.

George R. Yount
Rear Admiral, U.S. Navy
Co-Chairman, Clearance
Steering Group

Roy E. Beauchamp
Major General, U. S. Army
Chairman, Clearance
Steering Group

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ACKNOWLEDGMENTS

This study is a joint product. The Army, Navy, Air Force and Marines worked closely together to ensure a thorough review of all validated operational requirements. This work has given us a better understanding and appreciation for our respective missions and the UXO technologies required to support those missions.

The DoD staff elements which have primary responsibility for Humanitarian Demining and Environmental Security were important players in the effort to develop a unified, cohesive approach to the management of requirements and technology development for Unexploded Ordnance. The Office of the Director for Strategic and Tactical Systems served as the focal point on the DoD staff and chaired the DoD Executive Committee. The Joint Staff was also well represented and brought an important perspective to our efforts. The representatives from the Defense Advanced Research Projects Agency and the Office of the Director Test, Systems Engineering and Evaluation made important contributions to our work.

This study is the product of the efforts of dozens of men and women all across DoD who enthusiastically participated in this effort and joined the spirited debate which helped us understand the problems and craft a long-term plan of action. However, there are a few individuals whose support warrant specific recognition. Dr. Spiros Pallas, Mr. Andrus Viilu and Ms. Maureen Raley from the Office of the Director, Strategic and Tactical Systems were very helpful throughout this effort. Mr. Bob Doheny from the Office of the Assistant Secretary of Defense for Special Operations and Low Intensity Conflict played an important role in helping us shape a proposal which embraced all dimensions of the UXO problem. Mr. Richard Hess of the J-8 staff was also very helpful and supportive throughout the process. Special recognition is warranted for the Subgroup Chairmen for their outstanding work in leading their respective panels and working together in splendid teamwork to ensure a balanced, coordinated approach to these difficult problems. Captain Ted McCarley, USN, and Colonel Bob Greenwalt, USA, chaired the Requirements Coordinating Subgroup and did an outstanding job in harmonizing requirements across all five mission areas. Dr. David Heberlein did outstanding work as Leader of the Detection Technology Subgroup; Mr. Chris O'Donnell performed with equal distinction as Leader of the Neutralization and Disposal Subgroup. We are indebted to them for their technical support and the professionalism they brought to this effort. Mr. Dick Davis from the Department of Energy provided valuable support and helped lay the foundation for a fruitful and productive Interagency approach to the UXO problem. Mr. Bill Ervin, a contractor, provided valuable support and brought great enthusiasm to our effort. Ms. Gail Dempsey, a support contractor, did singularly outstanding work in helping us develop the UXO Technology Management Database which is a key feature of our long term program to manage this effort. The staff of the Army Materiel Command, notably Mr. Bob Jenkins, and the staff of the Night Vision/Electronic Sensors Directorate at Fort Belvoir, Virginia, and the staff of the Naval EOD Technical Center at Indian Head, Maryland were key and important players in developing this study.

Rear Admiral George R. Yount, USN, served as my Co-Chairman of the Clearance Steering Group. He provided, in enormous measure, technical expertise, management acumen, leadership, common sense and good humor. We are indebted to him for his support.

This team has helped us develop a new perspective and a coordinated, integrated approach to requirements and technology development to solve the difficult problems associated with Unexploded Ordnance Clearance. The Department of Defense has been well served by their efforts.

ROY E. BEAUCHAMP
Major General, USA
Chairman
Clearance Steering Group

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EXECUTIVE SUMMARY

The Department of Defense (DoD) is in the process of establishing an effective, fully-coordinated, requirements-driven research and development program for Unexploded Ordnance (UXO) Clearance technology. This program will coordinate and leverage technology advancements across the five DoD UXO Clearance mission areas: Countermine, Explosive Ordnance Disposal, Humanitarian Demining, Active Range Clearance, and UXO Environmental Remediation. An integral component of DoD's technology plan for UXO Clearance and detection is the development of private sector capabilities to perform these functions for Active Range Clearance and Environmental Remediation. The vast acreage at closing and active bases that require UXO clearance will require industry to play a leading role in developing improved detection and clearance technologies for these important missions.

The need for such a program has emerged over the past few years as U.S. involvement in operations other than war and post conflict humanitarian concerns have gained importance and as DoD has undertaken the closure of installations contaminated with UXO. As requirements for UXO clearance have increased, it has become apparent that similar technologies may be applied to UXO clearance activities in each of these areas. Such a coordinated technology development approach would not only be beneficial to the multiple user communities, but also to DoD to make efficient use of resources.

This report responds to direction from the House National Security Committee to submit a plan that defines research and development priorities, program management, and cooperative activities for technology applicable to area ordnance clearance. The report addresses General Accounting Office (GAO) concerns on the lack of an overarching, government-wide strategy or organization to leverage various technology development efforts to address the area ordnance clearance problem. This report describes a process which can be institutionalized within the DoD to maintain visibility over and potentially leverage technology efforts within DoD, at other government agencies, and in private industry, for the detection, neutralization, and disposal of unexploded ordnance.

In May 1996, DoD formed a multi-tiered Integrated Process Team (IPT) to act as a focal point within the DoD for the development of an integrated program for the development of technology to support land-based UXO clearance activities. This team consisted of an Executive Committee (EXCOM) of Senior DoD Officials to review these efforts and a Clearance Steering Group (CSG) to develop the program. The CSG reviewed UXO technology research, development, and acquisition activities to identify gaps in meeting operational requirements and to identify duplication across DoD programs. The CSG examined requirements supporting UXO clearance needs within DoD in five mission areas: Countermine, Explosive Ordnance Disposal (EOD), Humanitarian Demining, Active Range Clearance, and UXO Environmental Remediation. As part of this process, DoD formed joint service subgroups to review UXO requirements and technologies. The Requirements subgroup coordinated and harmonized operational requirements for the five mission areas. The technology subgroups – Detection and Neutralization/Disposal – identified technology developments for those operational requirements in all five mission areas. In addition, but not a part of this study, the Director of Defense Research and Engineering conducted a Technology Area Review and Assessment which provided an independent peer review of UXO science and technology programs and priorities. This review stressed research focus, quality and compliance with the Defense Technology Area Plan, Basic Research Plan and the Countermine Joint Warfighting Capabilities Objective in the Joint Warfighting Science and Technology Plan.

This study has identified the need to continue strong focus within the Department to ensure oversight and coordination of technology developments supporting UXO Clearance and to preclude duplication. The DoD is

taking steps to institutionalize coordination by setting up a UXO Center of Excellence to establish standards for testing, modeling, and evaluating UXO clearance technology. This UXO Center of Excellence will build on the work begun by the CSG to integrate DoD research, development, and acquisition activities for UXO clearance technology. The Center of Excellence will support the Joint Warfighters and Acquisition Communities and other programs in DoD such as the Joint Warfighting Science and Technology Plan (JWSTP), the Defense Technology Area Plan and the Basic Research Plan. The oversight of the UXO Center of Excellence will be provided by the Under Secretary of Defense for Acquisition and Technology through a Joint Board of Directors.

The UXO Center of Excellence will have a small core of Joint Service personnel in a Joint UXO Coordination (JUXOCO) Office to coordinate technology activities of the five mission areas and to exchange information on UXO technology with industry, academia, other government agencies, and international partners. The JUXOCO will serve as an integrating agent and information source. The key feature of the JUXOCO will be a comprehensive UXO Technology Management Database which will, for the first time, provide detailed information to users inside and outside the government. The JUXOCO will provide a single entry source into DoD for information on all UXO programs and activities. It will be a Joint activity located with the U.S. Army Material Command U.S. Army Communications Electronics Command Night Vision Electronic Sensors Directorate at Fort Belvoir, Virginia.

The Department of Defense has taken the preliminary steps to improve coordination of research, development, and acquisition of UXO clearance technologies and will work to expand coordination with other U.S. government agencies, such as the Department of Energy, and with industry and international activities. Initial measures have been taken to review UXO clearance requirements and survey programs and technologies either available or transitioning in the near future to meet the requirements. The creation of the DoD UXO Center of Excellence will provide strong focus to technology efforts supporting UXO clearance. DoD is moving in the right direction to leverage UXO clearance technology to solve the UXO clearance problem.

Unexploded Ordnance Detection and Disposal under all circumstances is a dangerous business. Effective solutions to the problem of UXO Clearance is a complex and difficult technical problem. An effective process to share technology, engage the best scientists and technologists, in and out of DoD, represents our best prospects for solutions to the UXO Clearance challenge. This study represents a joint program in DoD to achieve these objectives.

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Chapter One

Introduction

1.1. General

In response to provisions in the National Defense Authorization Act for fiscal year 1996, the Department of Defense (DoD) has taken steps to establish a formal structure within DoD to coordinate technology development efforts to support unexploded ordnance (UXO) clearance. It is the intent of DoD to establish an effective, fully-coordinated, requirements-driven research and development (R&D) program for UXO clearance technology. When fully implemented, the program will include other United States (US) government agencies such as the Department of Energy, and with private industry and international activities. It will take advantage of opportunities for leveraging technology development efforts in support of Countermine operations, Explosive Ordnance Disposal (EOD), Humanitarian Demining, Active Range Clearance, and UXO Environmental Remediation. The Department views this program as a positive step toward meeting the challenge to develop technology to more safely, effectively and efficiently detect, neutralize and dispose of UXO.

1.2. Background

UXO is explosive ordnance (1) that has been primed, fuzed, armed or otherwise prepared for action; (2) that has been fired, dropped, launched, projected, buried, or placed in such a manner as to constitute a hazard to operations installations, personnel or material; and (3) that remains unexploded either by design malfunction or for any other cause.[1]

UXO represents a global challenge. Collectively, 500 people per week in over 60 nations experience death and injury from approximately 100 million landmines left in place from prior conflicts.[2] Within the US, approximately 1,900 Formerly Used Defense Sites (FUDS) and 130 Base Realignment and Closure Commission (BRAC) sites require review for potential UXO ranging from small ordnance to large bombs. In addition, the US conducts testing and training on ranges that become contaminated with UXO over time.

Elimination of these UXO threats, especially antipersonnel landmines, has been the subject of congressional attention. The House National Security Committee (HNSC) cited the need for a central authority to plan, oversee, and coordinate the research, development, and acquisition of technology applicable to area ordnance clearance.[3] The HNSC directed the Secretary of Defense to submit a plan to the Committee that defines research and development priorities, program management and cooperative activity with international programs.[4] In a report to HNSC, the General Accounting Office (GAO), recommended the Secretary of Defense designate an executive agent to serve as a clearinghouse for research and development efforts within the Department for detection and clearance of UXO.[5] The GAO also recommended the plan include a proposal on how a multiagency

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[1]Joint Publication 1-02, Department of Defense Dictionary of Military and Associated Terms, 23 March 1994, p. 400.

[2]General Accounting Office Report B-258886, September 1995, pp. 1-2.

[3]National Defense Authorization Act For 1996, H.R. Rep. 104-131, p. 94.

[4]Ibid., p. 94.

[5]General Accounting Office Report B-258886, September 1995, pp. 18.

clearinghouse function could be performed to maintain visibility of federally funded research and development projects with applications to UXO detection and clearance.[6]

Five DoD mission areas are involved in UXO clearance: Countermine, Explosive Ordnance Disposal, Humanitarian Demining, Active Range Clearance, and UXO Environmental Remediation.

- Countermine missions are actions taken by a combat force to overcome mine obstacles to continue combat operations. These operations are usually performed by combat engineers to meet combat operational schedules, and they involve rapid breaching of mined areas.

- EOD is the detection, identification, field evaluation, rendering safe, recovery and final disposition of UXO. EOD operations are performed by trained technicians in small EOD teams during peacetime, war, and operations other than war. EOD operators are primarily focused on emergency response to UXO situations posing an immediate threat to life or property.

- Humanitarian Demining operations focus on the removal of residual landmine and other explosive hazards created from areas of regional conflict. The Humanitarian Demining program helps foreign governments develop an indigenous long-term infrastructure capable of eliminating landmine and associated munitions hazards within their borders.

- Active Range Clearance is the clearance of UXO on training and test ranges to permit continued safe and effective training and testing activities.

- UXO Environmental Remediation encompasses UXO issues related to site remediation of BRAC sites and FUDS for future public use.

1.3 Purpose

This report describes DoD's evolving formal program for coordinating and leveraging technology development efforts applicable to UXO clearance. It presents the concept for a coordination structure that would extend the technology coordination efforts to other government agencies and international efforts. It also addresses UXO clearance requirements and priorities across the mission areas to provide a framework for comparison of ongoing efforts to facilitate leveraging.

1.4 Department of Defense UXO Actions

The Department of Defense has taken steps to establish a coordinated approach to UXO clearance technology research, development, and acquisition activities. In May 1996, the Department established the three tiered integrated process team (IPT) structure, illustrated in Figure 1.1. The IPTs were tasked with ensuring that DoD has a coordinated, requirements-driven technology research and development program to support UXO clearance. The DoD executive committee and the steering group include representation from the military departments, the joint staff, and the Office of the Secretary of Defense (OSD) staff. The third tier of the IPT structure is made up of three working subgroups responsible for reviewing UXO requirements and technology development programs within DoD to ensure that they adequately address DoD's high priority requirements and are not duplicative.

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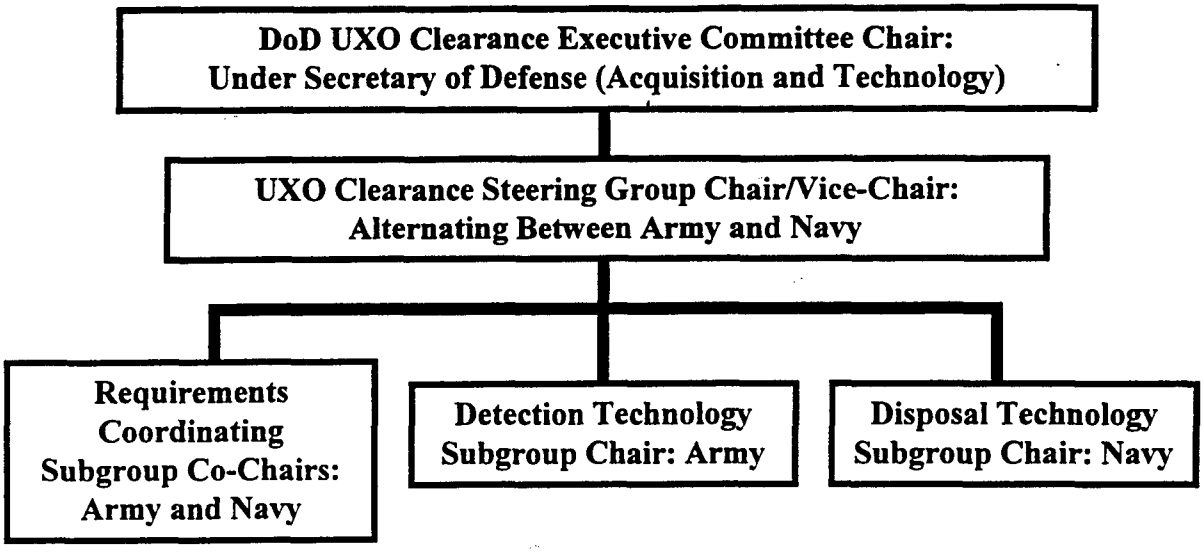
[6]Ibid., pp. 17-18.

Figure 1.1 DoD UXO Clearance Oversight Structure



The requirements coordinating subgroup conducted a thorough review of requirements for UXO clearance technology within the Department. Principal advocates from the five mission areas met as a community to analyze the requirements for each mission area. The subgroup identified 166 UXO requirements within the DoD. After sorting the requirements into basic functional areas common to UXO clearance, the subgroup examined the requirements in each functional area for the same or similar entries. This matching or coordination process reduced the number of requirements that meaningfully describe the needs of the five mission areas from 166 to 63 (Appendix A). The requirements subgroup will now work towards generating joint operational requirements. The 63 requirements were rated as high, medium, or low or no interest for applicability across multiple mission areas. This rating allowed the requirements subgroup to find potential joint requirement areas and also highlight areas where leveraging of technology would be most beneficial. The rankings do not provide a priority for the entire DoD UXO research areas because one mission area may have a critical high requirement that other areas have listed as no interest. Identification of the single mission area critical high requirements will also guide the DoD in applying research resources more effectively in each mission area. One community can now focus on a single critical item and leverage technology efforts in requirements that are funded in a joint interest area by another community.

The two technology subgroups (detection and disposal) matched the 63 requirements to existing and planned Department of Defense research and development activities. The subgroups evaluated current research and development efforts conducted in fiscal year 1997 and planned efforts in fiscal year 1998 against requirements for potential overlap, duplication, and deficiencies. Several technologies emerged with multiple ongoing research and development activities. It was determined that these activities were not duplicative. One example is the use of directed energy methods for neutralizing UXO from a standoff distance. The Countermine community is investigating kinetic energy kill mechanisms that provide a buried mine neutralization capability from a short standoff distance from a protected vehicle. The EOD community is studying the use of high power lasers to cause low order disruptions of small surface UXO from distances outside the UXO hazard radius.

In addition to the Executive Committee, DoD has identified the need for a Center of Excellence to coordinate standards for testing, modeling, and evaluating technologies for UXO detection and clearance. This Center of

Excellence will build on the work started by the DoD/IPT working groups and integrate DoD UXO clearance technology activities with other government agencies and international efforts. This Center of Excellence will serve as a clearinghouse for UXO technology data and information.

In developing this report, the DoD sought outside input. The DoD Executive Committee extended invitations to other government agencies to attend subgroup meetings. The UXO clearance steering group opened a dialogue with the Department of Energy (DOE). The Chairman of the UXO Clearance Steering Group visited DOE Savannah and Oak Ridge National Laboratories. DOE created an Interlaboratory Task Force on UXO with representation from ten of DOE's multi-program laboratories. This DOE Task Force surveyed existing and developing technology for UXO detection and disposal available within their laboratories and summarized this information into technology descriptions for inclusion in the DoD UXO database compiled by the Clearance Steering Group. The UXO Clearance Steering Group's interaction with DOE and its national laboratories has been mutually beneficial and serves as a model for future interagency cooperation. The DOE Interlaboratory Task Force Participants are shown at Appendix B. While the report covers these R&D programs directly funded by the Department of Defense, the DoD is leveraging technology base programs at DOE and other agencies. At the same time, the Department continued working Countermine and Humanitarian Demining issues with established interagency working groups, international organizations, and other countries with whom the US has existing Data Exchange Agreements (DEAs) in place, see Appendix C. On-going efforts also continued under DEAs that exist for coordinating UXO clearance technology between the U. S. Navy EOD Technology Division, the U.S. Army Communications and Electronics Command Night Vision and Electronic Sensors Directorate, and the Active Range Community and our allies. In the future, the Center of Excellence, in particular the Joint UXO Coordination Office (JUXOCO), will be the clearinghouse for coordination on UXO clearance technology research and development activities with other government agencies and international partners.

1.5. Report Layout

This report presents a requirements-driven program for UXO clearance technology research, development, and acquisition activities within the Department of Defense. Chapter Two discusses UXO clearance requirements, the UXO functional areas common to the mission areas, and the commonalities and differences among the UXO mission and functional areas. The chapter lays out UXO clearance requirements by mission and functional areas and visually shows requirements with maximum user interest. Chapter Three examines current UXO clearance technology research, development, and acquisition activities. The chapter discusses current technology capabilities in the inventory and technologies under investigation.

The report also describes an institutionalized process established in the Department to improve UXO technology coordination efforts. Chapter Four introduces the concept for a permanent DoD coordination structure to continue the progress made by the DoD IPT structure. This permanent coordination structure would serve as a clearinghouse for UXO technology activities conducted by DoD, other federal agencies, private industry, and foreign governments. Finally, Chapter Five offers summary comments on research, development, and technology management efforts to support UXO clearance.

Chapter Two

Requirements

2.1 Introduction

UXO presents a complex and difficult challenge. A wide range of military and civilian personnel must detect and neutralize thousands of different types of UXO including hundreds of different types of antipersonnel and antitank landmines. They must conduct clearance operations in all types of environments, climates, and terrains in hundreds of different scenarios. R&D efforts are needed to develop UXO clearance technology to improve the ability of clearance personnel to detect, locate, access, identify and evaluate, neutralize, recover, and dispose of UXO. Improved technology is also needed for breaching minefields and to support training of clearance personnel. The requirements subgroup collected requirements from each of the five mission areas, assessed them to identify areas of commonality and difference, matched similar requirements and solicited priorities by mission area. This chapter presents an analysis of the commonalities and differences of the mission areas requirements, lists the requirements, and identifies their level of interest by mission area.

2.2 Mission Area Commonalities and Differences

While there are many areas of commonality in the mission areas, there are also significant differences. The first difference involves the pace of operations. Countermine is a wartime function requiring rapid breaching operations potentially under hostile fire. It is characterized by a fast operational tempo (OPTEMPO). Humanitarian Demining, Active Range Clearance, and UXO Environmental Remediation are non-combat operations where the safety of UXO clearance personnel is paramount. These operations tend to be slower paced. EOD, on the other hand, can be both a combat and non-combat activity but tends to be slower paced than Countermine. The second difference involves the depth of UXO clearance required. Countermine and Humanitarian Demining concentrate on the detection and clearance of landmines from the surface down to depths of 2 feet. EOD, Active Range Clearance, and UXO Environmental Remediation clear a wider array of UXO than just landmines at depths from the surface to 20 feet or more. Figure 2.1 illustrates the UXO environment and type of UXO that may be encountered. The third difference involves the type of personnel which conduct UXO clearance activities. Trained military personnel conduct Countermine and EOD operations whereas civilian and contractor personnel generally handle UXO Environmental Remediation activities. Active Range Clearance is conducted by trained military personnel as well as DoD civilian and contractor personnel. Indigenous personnel perform Humanitarian Demining tasks but usually receive demining equipment and training from other nations, such as the US. The fourth difference involves the degree of reliability required in clearance activities. Countermine operations with a high OPTEMPO require a lower reliability in the range of 80-90 %. UXO Environmental Remediation and Humanitarian Demining require a high assurance of removal of the UXO and a reliability approaching 100%. The level of reliability required for Active Range Clearance depends on the reason for the clearance and how the range area will be used subsequent to clearance. In general, lower levels of reliability can be accepted during Active Range Clearance. Commonalities among the five mission areas include the need for accurate and timely information on detected UXO to plan clearance operations. All five mission areas require similar information on UXO present at a site to be cleared. Essential information on UXO location, type, quantity, and hazard affects the design and conduct of UXO clearance activities.

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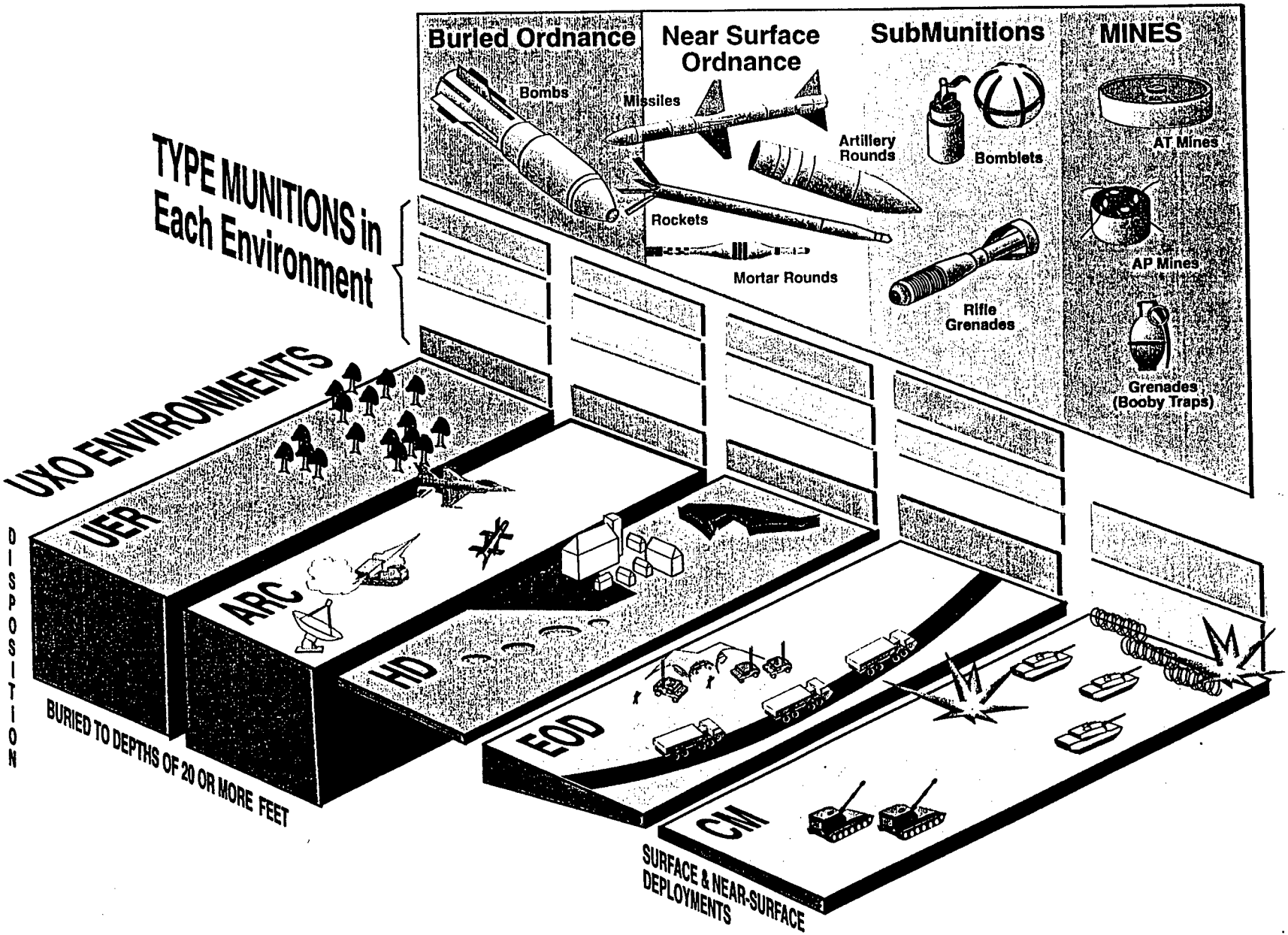
FIGURE 2.1 UXO THREAT



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The diversity of UXO clearance missions and sponsors has presented a challenge in efforts to establish common requirements and solutions to the UXO clearance problem. Sponsorship for each mission area varies widely, illustrating the need for a coordination mechanism. The five mission areas have central sponsors within the Department. Central sponsors include the Army for Countermine, the Assistant Secretary of Defense (Special Operations / Low Intensity Conflict) for EOD and Humanitarian Demining (the Navy is designated the single manager for EOD Technology and Training), and the Deputy Under Secretary of Defense (Environmental Security) for Active Range Clearance and UXO Environmental Remediation. Prior to this study, Active Range Clearance was performed at the Service's installation level and did not have a DoD central proponent. The Under Secretary of Defense for Acquisition and Technology has overall responsibility for technology development to support UXO clearance.

2.3 UXO Clearance Functional Areas

UXO clearance activities are a series of steps or functional areas common to the five mission areas. These common functions provide a framework to compare and describe the requirements for the five mission areas. Table 2.1 describes the common functional areas for UXO clearance.

Table 2.1 UXO Functional Areas

Functional Area	Description
Detection	Determine the presence of UXO
Location	Determine the precise geographic position of detected UXO. Includes actions to map or mark locations of detected UXO.
Access	Attain sufficient physical proximity to UXO by personnel and/or equipment to enable further actions.
Identification/Evaluation	Determine the specific type, characteristics, hazards, and present condition of UXO.
Neutralization	Actions taken to neutralize UXO either by preventing the functioning of the UXO or by intentionally disrupting normal operation of the UXO.
Recovery	Remove UXO from the location where detected.
Disposal	Dispose of UXO, once neutralized and recovered, by detonation in place or removal to an authorized disposal site.
Training	Techniques and devices that train UXO clearance personnel
Breaching	Methods that rapidly clear openings through minefields or areas containing surface munitions.

Detection of UXO is required by all five mission areas. The primary differences among the mission area requirements, as described previously, are the depth, search area, and speed of detection. All five mission areas require surface and near-surface detection capabilities; however, EOD, Active Range Clearance, and UXO Environmental Remediation require UXO detection at depths of 20 feet or more. Detection techniques that pinpoint UXO concentrations from large area searches are needed for UXO Environmental Remediation, Humanitarian Demining, and Countermine. Once UXO concentrations are detected, specific techniques are required to pinpoint individual UXO and landmines. Countermine

requires detection capability to find landmines as quickly as possible so combat engineers can safely traverse through the minefield while exposed to other threats.

Location requirements are also common to all five mission areas. Location requirements include mapping as well as either physical or electronic marking of the geographic position of the UXO. Countermine performs mapping and marking of mine locations to prepare for breaching operations or to enable mine avoidance to permit individuals and vehicles to safely traverse mined areas. All mission areas have requirements to map and mark UXO locations to facilitate planning and preparation for UXO clearance activities.

Access to individual UXO items is required by EOD, UXO Environmental Remediation, Active Range Clearance, and Humanitarian Demining activities to enable the follow-on clearance functions. Access includes the tactics, techniques, procedures and equipment to enable personnel and vehicles/equipment to safely attain physical proximity to the UXO required to conduct the follow-on clearance functions. Access includes the capability to defeat booby-trap features or use remote vehicles to examine and manipulate UXO. EOD must gain access to "first seen" or unknown UXO to render the item safe for future analysis, intelligence exploitation, or disposal. Active Range Clearance must gain access to developmental test articles for recovery and analysis.

Identification and evaluation is important to EOD, UXO Environmental Remediation and Active Range Clearance. Positive identification of the UXO and determination of its present condition are critical in safely conducting any follow-on neutralization, recovery, or disposal operations. Countermine and Humanitarian Demining may require identification of landmines to ensure application of adequate Countermine measures. Identification and evaluation involves techniques and equipment ranging from visual/physical actions to remote imaging and electronic interrogation of the UXO.

Neutralization capabilities are required by all five mission areas. Neutralization includes techniques, procedures, and equipment employed to prevent UXO from detonating or functioning. Neutralization may include actions such as removal, burning, or desensitizing explosives. UXO must be neutralized to enable recovery operations to be conducted safely. In addition to safety, neutralization operations must consider and comply with environmental laws and regulations. The performance of EOD render-safe procedures (RSPs) is a specialized neutralization technique. EOD RSPs involve the application of EOD tools and procedures to provide for the interruption of functions or the separation of essential components of UXO to prevent a detonation or munition function. In addition to military munitions, EOD forces require capabilities to neutralize all types of enemy and terrorist-improvised explosive devices.

Recovery involves the excavation and movement of UXO from the point of detection. In general, the recovery of ordnance that has been neutralized or rendered safe may be accomplished using standard materials-handling equipment. The requirement for remote recovery exists when the ordnance cannot be neutralized or when the condition of the UXO is unknown. All mission areas except Countermine involve recovery of UXO to varying degrees. EOD and Active Range Clearance recover UXO for evaluation or to transport to approved disposal locations. UXO Environmental Remediation and Humanitarian Demining may recover UXO for transportation to disposal areas.

Disposal is the final disposition or destruction of UXO. Disposal may be accomplished by detonation, thermal treatment, demilitarization, or disassembly and reuse of components. Detonation and thermal treatment are currently the most common disposal techniques. UXO Environmental

Remediation, EOD, and Active Range Clearance are the primary mission areas that conduct UXO disposal. Except for emergency EOD operations, disposal of UXO must consider and comply with environmental laws and regulations. Humanitarian Demining will generally dispose of UXO by detonation in place or removal to a disposal area.

Training consists of techniques and devices to train UXO clearance personnel. All five mission areas require training of UXO clearance personnel. Countermine involves training combat engineers on how to use minefield detection and breaching equipment under battlefield conditions. EOD requires detailed training on all ordnance that the EOD technician will encounter on the battlefield, in operations other than war, or during peacetime operations. As we move more in the direction of a civilian or contractor workforce for Active Range Clearance, training for that workforce on equipment and techniques to clear active ranges will be required. UXO Environmental Remediation will eventually require certification training of contractor personnel to search, locate, identify, excavate, and dispose of UXO found at BRAC sites and FUDs. Humanitarian Demining requires training of the indigenous workforce on how to use mine detection and clearance equipment in mine-clearing operations.

Breaching is a function unique to the Countermine mission area. Both Army and Marine forces conduct tactical breaching of minefields. These operations require speed and heavy equipment such as armored vehicles with plows, rakes, flails, and rollers to create safe lanes through minefields for follow-on tactical forces. Breaching is a fast-paced operation potentially accomplished under hostile fire.

2.4 Summary of Requirements by Mission and Functional Areas

The requirements coordinating subgroup categorized 63 UXO requirements in priority bands (high, medium, low, and no interest) for each of the five UXO mission areas to identify requirements that have multiple mission area interest. The subgroup will work in the future to develop joint requirement documents to refine and institutionalize these requirements to provide guidance for future research efforts. These same 63 UXO requirements are grouped by functional areas in the tables that follow.

2.4.1 Detection Requirements

Examples of detection requirements shown below in Table 2.2 include the requirement (#75) to detect surface and near-surface UXO. This requires 100 percent detection of all UXO on surface (including foliage-obscured) and sub-surface down to 6 inches. The system must be operable under adverse weather and terrain and cover up to 100 acres per day. The system requires Global Positioning System (GPS) or equipment-location accuracy with real-time data transfer. The requirement is a high-priority area in all five mission areas.

Another detection requirement (#103) is the need to detect and accurately locate UXO at the surface or buried down to 10 feet in any terrain. This requires the detection of metallic and non-metallic UXO of rates of up to 100 acres per day. This requirement is a high priority for all five mission areas. These two detection requirements are a representative sample of mission area requirements.

Table 2.2 Detection Requirements

Requirement Definition/Description	CM	EOD	HD	ARC	UER
Detector to search large areas and find UXO/UXO-free areas in a non-combat environment. (UXO ID #2)	M	M	H	L	M
Detect individual UXO including land mines with vehicle-mounted system in a non-combat environment. (UXO ID #4)	H	L	M	L	N
Detect all types of shallow buried UXO in all environments to a depth of 2 feet or less. (UXO ID #5)	H	M	M	H	H
Standoff capability to detect electromagnetic energy from standoff weapons that use internal sensors or command initiation. (UXO ID #6)	M	H	H	N	N
Detect and determine x-y-z axis location of all types of ordnance buried to a depth of 20 feet. (UXO ID #9)	N	M	N	H	M
Airborne system for detection of UXO including antipersonnel and antitank metallic and non-metallic mines on the surface or buried 2 feet or less. (UXO ID #11)	H	L	H	L	M
Tele-operated, remotely controlled, vehicle-mounted, high-speed detection and marking of UXO including anti-tank mines along a vehicle-wide path. (UXO ID #12)	H	L	M	L	M
Man-carried system to detect all UXO including antitank and antipersonnel mines at the surface or buried down to a depth of 2 feet. (UXO ID #13)	H	H	H	L	N
Remotely perform beach and inland minefield impact area/ reconnaissance. (UXO ID #14)	M	N	N	L	N
Detect all types of UXO at the surface or buried down to 6 inches. (UXO ID #75)	H	H	H	H	H
Detect and locate UXO buried to any depth down to 20 feet and possibly deeper. (UXO ID #76)	H	H	H	H	H
Perform rapid screening of large areas to determine presence or absence of UXO. (UXO ID #99)	L	H	L	L	H
Detect and accurately locate UXO at the surface or buried down to 10 feet or more in any terrain. (UXO ID #103)	H	H	H	H	H
Detect cases of glass vials or individual glass vials buried to any depth down to 2 feet. (UXO ID #110)	N	M	N	N	H

KEY: H=high interest, M=medium interest, L=low interest, N=no interest for the mission area indicated.

2.4.2 Location Requirements

The locate requirement receiving high interest across all mission areas (#112) in Table 2.3 is the need for an accurate UXO mapping capability. The system envisioned is an automatic digital mapping system that will accurately map UXO buried 20 feet deep to within one foot of the edge on the x, y, and z axes.

Table 2.3 Location Requirements

Requirement Definition Description	CM	EOD	HD	ARC	UER
Mark lanes breached through fields containing UXO, including mines, during combat conditions. (UXO ID #15)	H	N	M	N	N
GPS-linked physical/electronic system to mark UXO/UXO- free areas. (UXO ID #16)	M	H	M	N	L
Ruggedized in-flight munition tracking system for use during development and testing of munitions. (UXO ID #80)	M	N	L	H	L
Automatic digital Geographic Information System (GIS) to record location of detected ordnance. (UXO ID #112)	H	H	H	H	H
Automated digital (GIS) to record the location of detected ordnance underwater to a depth of 300 feet. (UXO ID #113)	L	M	N	L	L
Automated database system to collect, store, analyze, and disseminate information on areas containing UXO/minefields. (UXO ID #163)	H	H	L	M	H

2.4.3 Access Requirements

Multiple mission area interest in Access Requirements is strongest in areas where the user must directly interact with the UXO. Access requirement (#27) in Table 2.4 is for an individual protective ensemble to reduce injuries from blast and fragmentation for personnel working in proximity to UXO. The ensemble supplements the standard helmet and protective vest. Another requirement (#28) is for a tactical wheeled vehicle protection kit to protect the crew in a UXO/mine threat environment. A third requirement (#87) is for improved robotics with increased range of motion and advanced manipulation capabilities to work close-in with UXO. The system should be developed for backhoes and all-terrain vehicles.

Table 2.4 Access Requirements

Requirement Definition/Description	CM	EOD	HD	ARC	UER
Personnel protection ensemble to increase survivability from explosive blast and fragmentation. (UXO ID #27)	M	H	M	H	L
Kit to protect against detonation damage to wheeled vehicles. (UXO ID #28)	M	H	M	H	L
Defeat antidisturbance feature of all types of ordnance. (UXO ID #37)	M	H	L	L	N
Personnel protection for performing EOD mission in toxic environment. (UXO ID #39)	N	M	L	L	L
Method required to gain access to internal area of UXO for the purpose of removing explosives or providing direct access to embedded fuzing systems. (UXO ID #57)	N	H	L	L	N

Requirement Definition/Description	CM	EOD	HD	ARC	UER
Improved robotics or remote-controlled systems for gaining access to and recovering ordnance. (UXO ID #87)	M	M	M	H	M
Underwater automated UXO excavation and recovery equipment. (UXO ID #119)	N	L	N	M	L

2.4.4 Identification Requirements

Requirements in UXO identification are a high priority to operators who must render a UXO safe without causing collateral damage. Requirements in Table 2.5 include the ability to ensure UXO are inactive. This means the ability to monitor the state of electronics and mechanical fuzing while setting up and performing EOD procedures. It also means the ability to identify UXO by type and determine the condition of subsurface UXO at the rate of 100 UXO items per hour with 98 percent accuracy. Both of these requirements (#38 and #116) are high with EOD and UXO Environmental Remediation mission areas.

Table 2.5 Identification Requirements

Requirement Definition/Description	CM	EOD	HD	ARC	UER
Identify all known chemical/biological agents in any physical state. (UXO ID #8)	M	H	L	L	H
Monitor status (armed/unarmed) of electromechanical fuzes during EOD operations. (UXO ID #38)	M	H	L	L	H
Man-portable system capable of imaging ordnance buried to a depth of 10 feet with sufficient resolution to permit identification by type (i.e., bomb, rocket, projectile). (UXO ID #41)	L	M	H	M	H
Man-portable system that provides 3-D image of internal features of ordnance that is not buried. (UXO ID #43)	N	M	L	L	L
Examine standoff weapons without actuating sensors. (UXO ID #44)	L	H	L	L	N
Man-portable system to provide 3-D image of external features of ordnance on the surface or buried to 2 feet and positively identify ordnance by automated comparison/search of database. (UXO ID #45)	L	L	L	M	M
Image internal features of ordnance buried to 10 feet. (UXO ID #46)	N	L	L	M	L
Remotely determine status of electronic fuze. (UXO ID #47)	L	M	L	M	H
Determine explosive material composition. (UXO ID #49)	L	M	L	M	M
Rapidly acquire and evaluate intelligence information on UXO. (UXO ID #52)	L	M	M	L	N
UXO identification by type. (UXO ID #116)	L	H	L	L	H

2.4.5 Neutralization Requirements

All the mission areas concerned with surface UXO clearance highly rank neutralization requirement (#62). This would provide a protective mobile system capable of neutralizing or rendering safe large quantities of UXO from a safe standoff distance of 50-450 meters (Table 2-6). Another requirement (#61) is a man-portable system to desensitize explosives to permit safe separation and removal of explosive components. These two requirements have applications across all five mission areas. Neutralization requirements are found in every mission area and are especially important because clearance personnel are confronted with making decisions on what to do with detected UXO.

Table 2.6 Neutralization Requirements

Requirement Definition/Description	CM	EOD	HD	ARC	UER
Clear UXO, including antipersonnel mines, over extended areas in a non-combat environment. (UXO ID #1)	M	L	H	M	L
Neutralize magnetically fuzed UXO, including antitank mines, buried to any depth up to 2 feet. (UXO ID #24)	H	M	L	L	N
Prevent arming or firing of influence fuze while EOD procedures are performed. (UXO ID #36)	M	H	M	N	N
Neutralize to protect EOD personnel and contain contamination until final disposition. (UXO ID #50)	N	L	N	N	N
Tool that can produce frequencies capable of switching electronic fuzes back into a safe condition. (UXO ID #55)	L	H	L	N	N
Remotely neutralize unseen, hidden, or embedded electronic fuze systems. (UXO ID #56)	M	H	L	N	N
Permanent or temporary desensitizing of explosive material to allow for the separation of hazardous components. (UXO ID #61)	M	M	M	M	H
Rapidly neutralize large quantities of UXO over a large area by remote/stand-off means. (UXO ID #62)	M	H	M	H	H
Neutralize/render safe vehicle improvised explosive devices. (UXO ID #166)	M	H	N	N	N

2.4.6 Recovery Requirements

Active Range Clearance requires a blast-protected system (Table 2.7) that can be driven over ranges to pick up shrapnel and other non-hazardous residue. The system should be able to cover 100 acres per day for heavily contaminated areas and 200 acres per day for lightly contaminated areas.

Table 2.7 Recovery Requirements

Requirement Definition/Description	CM	EOD	HD	ARC	UER
System to recover shrapnel and other nonhazardous residue. (UXO ID #94)	N	N	M	M	L

2.4.7 Disposal Requirements

Active Range Clearance, EOD, and UXO Environmental Remediation have strong interest in proper disposal of UXO. Disposal requirements (Table 2.8) include lightweight (man-portable) materials and systems for construction of blast and fragmentation barriers and protective devices and a remotely operated system to remove submunitions from roads and flat terrain. A need exists to safely handle range residue. The system should be mechanized and provide a cost-effective alternative to manual collection and subsequent certification that range residue is inert.

Table 2.8 Disposal Requirements

Requirement Definition/Description	CM	EOD	HD	ARC	UER
To capture, separate, treat, and contain hazardous waste and toxic materials in a suitable condition while awaiting final disposition. Environmentally safe handling, movement, storage, and disposal procedures to eliminate the need for long term and costly handling. (UXO ID #63)	N	L	N	H	M
Mechanized system for certification of range residue as inert. (UXO ID #89)	N	N	N	H	L
Remotely operated system to remove submunitions from roads and flat terrain. (UXO ID #93)	M	H	M	H	L
Lightweight blast and fragmentation barriers. (UXO ID #121)	M	H	L	L	H

2.4.8 Training Requirements

The acquisition of surrogate mine and UXO for use as training aids is a training requirement (Table 2.9). These training aids will assist in the training of personnel in all five mission areas.

Table 2.9 Training Requirements

Requirement Definition/Description	CM	EOD	HD	ARC	UER
Surrogate mines and UXO for training. (UXO ID #30)	M	H	M	M	M

2.4.9 Breaching Requirements

Breaching requirements (Table 2.10) reside largely in the Countermine mission area. Breaching requirements support the need for combat forces to rapidly transit mined areas to minimize casualties and sustain the pace of combat operations. Some breaching requirements reside in Humanitarian Demining

and EOD mission areas. These requirements represent needs by deminers and EOD to have the capability to self-extract personnel and equipment when trapped in mined areas.

Table 2.10 Breaching Requirements

Requirement Definition/Description	CM	EOD	HD	ARC	UER
High-speed, explosive breaching of antitank and antipersonnel mines on land or in shallow water. (UXO ID #19)	H	N	N	N	N
Mounted high-speed breaching through heavily defended minefield. (UXO ID #20)	H	N	N	N	N
Breach footpaths through anti-personnel land mines and light wire obstacles with a man-portable system from a position outside mine lethal distance. (UXO ID #21)	H	N	N	N	N
Man-carried line charge to breach anti-personnel mines on the surface under combat conditions to facilitate self-extraction from mine field. (UXO ID #22)	H	L	L	N	N
Self-extraction and protection plows and rollers for tank forces. (UXO ID #23)	H	L	L	N	N
Clear mines and obstacles in a 50-meter-wide lane through the surf zone and beach in order to land Landing Craft Air Cushion (LCAC) landing zone operations during amphibious assaults and inland expeditionary operations. (UXO ID #25)	H	N	N	N	N
Rapidly clear large beach areas for LCAC landing zone operations during amphibious assaults and inland expeditionary operations. (UXO ID #26)	H	N	N	N	N
Remotely operated system to detonate or neutralize UXO/mines. (UXO ID #29)	M	M	H	L	L
Conduct an in-stride explosive breach of antipersonnel and antitank mines under combat conditions (UXO ID #33)	H	N	N	N	N
Clear the surf zone (SZ) and beach zone (BZ) of mines and obstacles in order to land LCAC during amphibious assaults and expeditionary operations. (UXO ID #161)	H	N	L	N	N

2.5 Requirements: The Way Ahead

The DoD through the Center of Excellence structure, described in Chapter Four, will periodically review technology requirements supporting UXO Clearance. The purpose of these reviews will be to ensure current needs of the five mission areas are accurately captured and broadcasted to potential technology centers capable of providing technology solutions. The Joint UXO Coordination Office (JUXOCO) will complement and facilitate the requirement review process by being a source of information and support to the five mission areas. The Joint UXO Coordination Office will maintain an accurate database of UXO technology and technology development activities on-going within the five mission areas. The end result of the requirements review process will be accurate and current technology requirements for UXO clearance.

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Chapter Three

Technology

3.1 Introduction

The purpose of this chapter is to review the ongoing research, development, and acquisition efforts in the Department of Defense that support the UXO clearance mission. The DoD is investing $129.4 million in technology development to support UXO clearance in fiscal year 1997 and will invest $174.6 million in fiscal year 1998 (Appendix D). The largest portion of these funds goes to Countermine. In addition, the Department of Energy and other agencies support the development of technology specific to their assigned missions that can be leveraged to support DoD's UXO detection and disposal missions. This Chapter identifies existing capabilities, current programs, and research and development efforts and evaluates those efforts against the needs of the entire DoD UXO community. Appendices E and F illustrate some of the ways the detection and disposal capabilities discussed in this chapter are or might be used in the future to clear UXO.

UXO clearance presents an extremely difficult technical challenge. We have not yet solved these problems though our science and technology programs are beginning to yield good results. This chapter is organized into six subsections to discuss these technologies beginning with our current capabilities and concluding with a more detailed discussion of the technologies associated with UXO clearance. Continued investment, within the limits of affordability, in these future technologies is essential to make the best technology solutions available to address the important national priorities in all five mission areas.

Each subsection explains the capabilities or ongoing work in each mission areas in the functional order that a UXO clearance task would be performed in the field. The operator must first detect the item, then gain access to an object. At this point the decision would be made to breach a path through the UXO or to individually clear each item. If each item must be cleared, the operator would identify the UXO, detonate, neutralize or render safe the item, recover the item and finally dispose of the UXO. Using this order allows for direct comparison of capabilities between the communities.

3.2 Current Capabilities

Each community has existing capabilities to perform various UXO clearance functions. In this section, equipment that is currently fielded and in use is discussed. The equipment in this area varies from logistically supported equipment, to rapidly fielded prototypes, to commercial off-the-shelf (COTS) equipment. The equipment discussed is used on a daily basis by military and/or commercial operators in support of the wide range of tasks supported by the five mission areas. Efforts to develop training aids are also discussed.

Table 3.1 Current Capabilities

Countermine		
	Detection	Hand held mine detectors (AN/PSS-11, AN/PSS-12), probes, tank-mounted rollers
	Location	Bonnets, fences, Hand Emplaced Minefield Marking System (HEMMS)
	Breaching	Battalion Countermine Set (and equivalents), Mine Clearing Line Charge (MICLIC), manually placed charges
	Access	Body Armor Set, Individual Countermine (BASIC), Chemical protective garments, vehicle crew protection kits, Mine Resistant Vehicle (MRV)
	Neutralization	Launched Grapnel Hook, PANTHER, Mini-Flail, manually placed charges
Explosive Ordnance Disposal		
	Detection	MK-22, MK-26, MK-29, AN/PSS-12, ITI Model 97
	Identification	Advanced EOD Publications System (AEODPS), MK-32, MK-10
	Access	Individual training, commercial bomb suits, Remote Controlled Transporter (RCT)
	Neutralization	Techniques including Small Arms Munition Disrupter (SMUD), Blow-In-Place (BIP), Pick-Up-and-Carry-Away (PUCA), and Render Safe Procedures (RSP)
	Recovery	Field expedients
	Disposal	Open burn or detonation
Humanitarian Demining		
	Detection	Leashed mine-detection dogs, mini-mine detector
	Location	Mine marking foam
	Neutralization	Liquid Explosive Foam (LEXFOAM)
	Disposal	Enhanced Mini-Flails
	Training	Mobile training systems, Minefacts CD-ROM, Bosnia File
Active Range Clearance		
	All areas	Commercial Off The Shelf (COTS) or military adapted-equipment, EOD technicians, DoD civilians, locally hired service contractors
Environmental UXO Remediation		
	All areas	COTS or military adapted equipment, service contractors

3.2.1 Countermine - Current Capabilities

Today, metallic mines and low metallic content mines are detected by induction coils. The close-in detection capability currently used by the combat engineer company in the DoD inventory is the AN/PSS-12 (Army), and its predecessor, the AN/PSS-11 (USMC). They have the capability to detect metallic components of mines, but no capability to detect nonmetallic mines. The AN/PSS-12 is capable of detecting small quantities of metal. Unfortunately, areas that are seeded with land mines may also have a significant amount of metallic debris, as the result of combat. As the sensitivity of the AN/PSS-12 and AN/PSS-11 are increased, the number of false detections resulting from the metallic debris also

increase. Neither detector has the capability of distinguishing metallic debris from a metal component of an intact, potentially lethal landmine.

Nonmetallic probes are available to assist in the detection and removal of mines. The mounted armor force has tank-mounted mine rollers available that can be used to detect the forward edge of a minefield by encountering mines (detonating them). Mine rollers are not effective against complex fuzed and standoff mines. Rollers and probes work very well for what they were designed to do.

Once detected, the location of minefields and individual mines must be marked. Marking of mines is accomplished by placing cardboard or plastic "bonnets" at the location of each target. Minefield marking is accomplished by manually emplaced fences, typically three-strand cattle fences of barbed wire, with triangular shaped "mine" signs hung from the upper strand of wire. The current minefield lane marking system, HEMMS (Hand Emplaced Minefield Marking System), proved to be ineffective and labor intensive when used in Operation Desert Storm. A new vehicle-mounted marking system is envisioned as a replacement.

The Army and Marine Corps both field vehicle-based explosive systems for the breaching of antitank mine fields. The Army has the Battalion Countermine Set that provides plows, rakes, and magnetic signature equipment for tanks. A limited number of similar systems were procured for light armored vehicles in support of operations in Bosnia. The Marine Corps also utilizes plows, rakes and magnetic countermeasure systems, but a majority of these capabilities are classified as contingency items. Explosive breaching is performed with the Mine Clearing Line Charge (MICLIC) deployed from a number of fixed-vehicle and trailer-mounted configurations for both services. Breaching of antipersonnel minefields is currently conducted using manual techniques. The typical technique is detonating mines by placing a block of explosives next to each mine and detonating it, causing sympathetic detonation of the mine.

The Army currently has a Launched Grapnel Hook (LGH) for initiating trip wires. Other current booby trap access tools are more properly described as techniques and rely on the experience of the operator. Information gathered on booby traps, both by US and foreign forces, is shared through the intelligence community.

Remotely controlled vehicles are recent additions to the Services' inventories of tools. The Army combat engineers have used two systems in Bosnia. The first is a modified M60 tank chassis with mine rollers called the Panther used to assist in clearing or proofing vehicular routes. The second is a small, skid-steered platform with a flail called Mini-Flail, which clears footpath width trails through antipersonnel mines.

Clearing of minefields in a combat environment is only conducted to facilitate future operations or allow the area involved to be used for a specific purpose, such as a logistics base. These clearing operations are currently conducted using manual techniques, with individually placed explosive charges.

Combat engineers use protective garments to reduce the hazards associated with inadvertent initiation of UXO. These include standard helmets, flak jackets, specialized leggings, and over boots for antipersonnel landmine clearance. This ensemble is called BASIC (Body Armor Set, Individual Countermine).

The combat engineer called on to handle UXO with a chemical or biological filler relies on currently

fielded chemical warfare suits. These suits are bulky and reduce the operators ability to perform dexterous tasks that are required for some UXO missions. The acquisition of chemical and biological equipment is performed by a joint service executive agent.

The Army has fielded the Crew Protection Kit (CPK) to protect both HMMWVs and 5-ton trucks from the effects of mine blast. Kits were also rapidly developed and sent to Europe for Heavy Expanded Mobility Tactical Trucks (HEMMT) and Palletized Loading System (PLS) vehicles. The Army has also fielded an armored version of the HMMWV that may have applications as a platform for area and route clearance technologies. Additionally, a Foreign Comparative Test (FCT) program resulted in the purchase of five Mine Resistant Vehicles (MRV) for possible use in Bosnia.

3.2.2 Explosive Ordnance Disposal - Current Capabilities

The EOD technician currently has four systems for the detection of UXO. These hand-held systems are based on the detection of ferrous and other metallic components of the UXO. The MK-22 Detector is a modified Geometrics 822L cesium magnetometer used by the Army EOD technicians. The MK-22 is a total field magnetometer that provides the capability to detect and locate buried ferrous objects by a secondary magnetic field induced by the UXO's disturbance of the earth's magnetic field. The operator is cued by an aural tone that provides an intensity reading. The MK-26 Detector is a modified Forrester Ferex gradiometer used by Marine Corps EOD technicians. The MK-26 provides the ability to detect and locate buried ferrous objects by measuring the difference of the magnetic moments caused by the secondary field. The operator is provided an aural and visual signal of the intensity of the disturbance. The MK-29 All Metal Locator is a modified Vallon MW1630 used by Navy EOD technicians for surface and underwater tasks. The MK-29 is a pulsed inductance locator that provides the capability to detect and locate small metallic components for both surface and underwater missions. The operator is provided an aural signal that reports the local intensity of metallic objects. Army and Air Force EOD technicians also use the PSS-12 Mine Detectors. The US Army EOD forces have purchased the ITI Model 97 Explosive detector. This detector uses a gas chromatography-electron capture detector approach to detecting the presence of explosives. This man-portable detector suffers from a low detection probability and high false alarm rate in a military environment. Detection of surface-scattered ordnance is performed by visual reconnaissance. Location of UXO is performed by placing a small colored flag next to the surface UXO or in the ground at the center of detection of a buried anomaly.

The EOD technician performs identification of UXO by visual inspection and comparison to the EOD 60-Series publications. The 60-series contains 2600 publications that provide information on over 6,000 UXO items. Recently, the 60-series was published on two CD-ROMs to form the Advanced EOD Publication Series (AEODPS). The AEODPS contains a search system that allows the user to input key features of the UXO and provide a list of probable ordnance items that have these features. The EOD Technician also has the MK-32 X-Ray system to inspect internal features of the UXO to determine status of the fuzing mechanism. The Marine Corps performs in field exploitation of UXO by using the MK-10 Chemical Kit. This device is used to identify the explosive fill of the UXO prior to disassembly of the item. A small number of Army and Navy EOD teams also have specialized booby trap detection equipment developed for counter-terrorism operations.

The ability to access an area that contains UXO, while eliminating or mitigating the hazards associated with functioning of the UXO, relies heavily on the skill of the individual operator or the use of remote vehicles. EOD Technicians use standard helmets and flak jackets and have specialized "bomb suits" purchased from commercial companies for handling improvised explosive devices. In either case,

the protective ensembles increase fatigue for the operator and inhibit motion. All four services have fielded the Remote Controlled Transporter (RCT) as a non-developmental item based on the Westinghouse Andros MK6 platform. This system is primarily used for improvised explosive devices and is of limited use for UXO because of system speed and lack of manipulation capabilities.

The EOD technician performs neutralization of UXO through the use of manual techniques. Tools for these techniques range from screw drivers and crimpers to shaped charge and cartridge actuated devices. There are 27 different logistically supported hand tools in the joint service EOD inventory. These manual techniques are performed as Render Safe Procedures (RSPs) using the different EOD tools. These procedures are time-consuming and are used when collateral damage is not acceptable. The technician can also use the MK 127 Fuze Neutralization Kit to remotely immobilize the internal parts of mechanical fuzing devices. The system automatically mixes and injects thermosetting polymers into mechanical fuzes to prevent the movement of components. In a operational scenario for clearing large numbers of threat-specific antipersonnel mines and submunition types, three different methods are used. The Small Arms Munitions Disruption (SMUD) is a technique of using a rifle to shoot the UXO from a protected area and cause detonation or disruption. This technique relies on the marksmanship of the operator and can cause a more hazardous situation by damaging the UXO. Blow In Place (BIP) is a technique of putting a block of explosives next to the UXO item and causing a sympathetic detonation. This technique is time-consuming for multiple items and can cause a larger hazard if all the UXO items are not destroyed. The most hazardous method is Pick Up and Carry Away (PUCA). This is a technique of examining the UXO item, then manually moving it to a central disposal area. The operator is put at great risk due to inadvertent initiation of the UXO. Render Safe Procedures (RSPs) using specialized EOD tools can also be used. These procedures are time-consuming and are used when collateral damage is not acceptable.

The EOD technician performs recovery of UXO from underground or to a centralized location with hand tools, standard hauling vehicles, and construction equipment.

EOD disposal of UXO is normally performed by open burn or open detonation near the area where the UXO was discovered. The UXO is normally in an unsafe condition for transportation and is destroyed for that reason. If the item is transported, the MK 634 Explosive container is used. The MK 634 or the Total Containment Vessel (TCV), is a spherical steel vessel mounted on a low tandem commercial trailer. It is used to transport and dispose of explosive devices. It is designed to totally contain the blast effects of a charge up to 10 pounds of TNT or a 60mm mortar shell. The EOD technician can also use the MK 62 Steam Generator to steam out the explosive filler of larger UXO.

3.2.3 Humanitarian Demining - Current Capabilities

Current capabilities in Humanitarian Demining operations rely on the Army's hand-held detectors, mine probes and marking material and demolition items. Since 1995, under the auspices of OASD SO/LIC and being executed by the Night Vision and Electronic Sensors Directorate's Demining Branch, the Humanitarian Demining Technology Development Program has identified, developed and evaluated several new and innovative demining equipments making use of COTS equipment and technology leveraging, and government in-house development activities using rapid prototyping techniques when industry was not prepared to undertake the venture. The goal of this program is to rapidly get the most advanced equipment into the hands of the demining community. Many of the technologies must be used by indigenous personnel or by non-government organizations (NGO's) having limited formal education. Therefore, these technologies must be simple to learn, easy to use and maintain, while remaining host-

nation or "donor organization" affordable.

Several of the Humanitarian Demining technologies developed and evaluated by the U.S. demining technology development program have demonstrated high potential and are currently in use, or being fielded by government and non-government organizations (NGO) to augment or optimize existing military countermine equipment. They include: mine detection dogs, special purpose hand-held mine detectors, mine-marking and neutralization foams, liquid explosive foam (LEXFOAM), improved Mini-Flails, multi-lingual multi-medial mobile training systems, mine awareness training items (CD ROM Mine Data Bases and Educational comic books) and high-speed air knives for safely uncovering suspected mines.

Mine detection dogs from the SO/LIC/NVESD program, specifically the leashed dog/handler mine detection dog teams, are currently in Bosnia. These dogs are under handler control when operating in suspected mined areas. Once a mine or trip wire has been detected, they alert the handler by pointing their nose at the target and sitting next to the suspected mine or trip wire.

The mini-mine detector is a battery-powered, hand-held, miniature metal detector that detects buried mines with metal content as low as one gram. The unit is especially designed to be operated while in a prone position and can be folded and transported in a deminer's pocket, making it available at all times for emergency mine detection or extraction from a minefield.

The mine marking and neutralization foam is a polyurethane foam that rapidly hardens once applied to a mine or tripwire device. The foam impregnates the exposed portions of the mines and then hardens, rendering the fuze inoperative. Additionally, a "pull cord" can be fastened to a mine or items by "gluing the cord to the device with the foam; the cord can then be pulled to remove the item from its location without danger of exposure to anti-handling devices. The hardened foam does not destroy mines, but it does ensure the mines are safe for subsequent neutralization. The bright orange color of the foam clearly marks the mine's position. A man-portable dispenser applies the foam on the mine.

LEXFOAM is a nitromethane-based liquid explosive foam designed as a commercial blasting agent. Its light weight foam and consistency enable deminers to spray it directly onto an item without danger of activating it. This plus its great cost effectiveness makes it both desirable and effective for in-situ landmine and possible UXO neutralization. The closed cell structure of LEXFOAM gives this technology a greater shattering effect than explosives of the same weight and density. Two delivery systems are used: the man-portable backpack version and the palletized version for large open areas accessible by military or commercial trucks. LEXFOAM's physical and chemical characteristics prevent it from being used as a military weapon. Until sensitized it is able to be transported and stored as highly flammable liquid, and when deployed the foam will evaporate in a matter of hours.

The improved Mini-Flail is a remotely controlled, skid-steer loader modified with a rotating flail head designed to clear antipersonnel mines in on-road/off-road environments. Improvements include: remote controlled flailing head rotation reversal, lighter armor, improved integration and protection of internal electronics package, and improved tires for better blast protection and traction.

The mobile training system is a suite of multi-media audio and visual computer equipment that is able to provide both mine awareness and demining mission training to host nation people. The effective training on mine recognition, safety procedures and demining situation training techniques provided by this system is a significant means of reducing casualties due to land mines by civilian populations and

deminers. These systems are being purchased for deployment to Europe, Central America, Africa and Asia. Educational multi-lingual comic books and an updated Minefacts CD ROM containing a worldwide mine database are also available as training items.

3.2.4 Active Range Clearance - Current Capabilities

Nearly all active test and training ranges are supported by military EOD units that have the standard suite of EOD equipment. Detection of surface UXO is primarily accomplished by visual reconnaissance -- a labor-intensive and dangerous method that puts clearance personnel in close proximity to UXO. Hand-held systems that can detect metallic components of UXO are available at most ranges, however, they are impractical for many active range missions due to extremely high rates of false detection experienced in highly cluttered (shell fragments, shrapnel, etc.) target areas.

In addition to standard EOD equipment, some ranges have made investments in procuring and/or developing specialized tools and equipment. The capabilities described below exist at one or more of the active ranges.

Radar, optics, and telemetry data are used by some ranges to track test munitions and locate their impact sites. Commercial excavators and wheeled/tracked vehicles, equipped with remote control packages and video capabilities, are used to recover unexploded experimental munitions at a safe distance. The excavators are capable of digging to depths of 30 feet, and can lift up to 20,000 pounds. The wheeled/tracked vehicles, equipped with extendible lifting arms and/or manipulator arms capable of lifting up to several hundred pounds, are used during the recovery, inspection, and disposal of UXO. The manipulator arms have the dexterity to remove and disassemble fuzes and components from UXO. Standard EOD robots are also available at several ranges, some of which have been modified to achieve faster speeds and increased range of operation. M113A2 Armored Personnel Carriers have been fitted with hydraulic arms and are used by clearance personnel to safely approach and lift UXO. An M60 Tank, modified to include remote video and commercial digging capabilities, has been used to safely recover UXO. In addition, all-terrain vehicles are employed at some ranges to aid in search operations.

During the course of a range clearance exercise, trained personnel remove or dispose of unexploded ordnance, classified ordnance, inert ordnance residue, training projectile ammunition, and other range material. EOD or other trained personnel inspect ordnance residue and render safe unexploded ordnance by detonation or burning (where allowed). The current process for inspecting range residue and the certification that the said residue contains no dangerous items is inefficient and can lack adequate reliability needed to ensure the safety of civilian personnel handling the residue after disposal. The inspection of range residue is a visual inspection conducted by qualified personnel. Each and every piece of residue is manually inspected.

3.2.5 UXO Environmental Remediation - Current Capabilities

UXO Environmental Remediation is primarily carried out through government contracts for UXO services (UXO characterization, UXO excavation, etc.). The technologies used to support UXO Environmental Remediation are commercial equipment available across the industry. Surface detection is performed manually through visual inspection without the aid of any sensors. The subsurface UXO detection utilizes magnetometer, gradiometer, or electromagnetic induction sensors and combinations thereof. Equipment used is either provided by the government as Government Furnished Equipment (GFE) or provided by the remediation contractor. Typical sensors employed include the Forester Ferex

MK26, Shonstedt gradiometers and other commercially available equipment. Sites are traditionally surveyed by using these sensors in an analog mode where the operator identifies an anomaly and places a flag at the location for future investigation. To a limited extent, newer detection systems that record the data digitally for off-site assessment and record the location of the suspected item electronically are beginning to be exploited. The effectiveness of these systems is limited by significantly high false alarm rates induced by man-made and geological clutter. Current technology has exhibited minimal discrimination capabilities - the ability to differentiate between hazardous ordnance items and nonhazardous debris. Often as many as 95% of suspected anomalies are nonordnance items. Due to these limitations, approximately 70% of the costs to remediate a UXO site is spent excavating these nonordnance items.

Assessments of over 60 commercially available systems were conducted during Congressionally mandated Advanced Technology Demonstrations (1994-96). The latest round of demonstration results are not yet released. There appear, however, to be promising improvements in detection rates. Unfortunately, the correspondingly necessary reductions in false alarm rates and improvements in discrimination capabilities are not yet in evidence.

The current and most widely used method for UXO excavation is digging by hand. However, single, unique remote vehicles, adapted from commercially available vehicles, have been occasionally used for remediation for a number of years. Although remote vehicle costs are usually higher than hand excavation, safety hazards to workers can be significantly reduced.

3.3 Transitioning Technologies

3.3.1 Introduction

For technology and programmatic discussion the UXO and mine clearance technology problem falls into two general areas: detection and disposal. Subgroups were created and empowered to look into each of these major technology areas. The remainder of this section presents their efforts.

Because of the enormity and diversity of the UXO problem, there is not a single technological "silver bullet" that will provide a universal solution. Detection solutions include aggressive investigations of a variety of sensor technologies, singly and in combination and a thorough understanding of the signatures of UXO and the cluttered environments in which they are located. Disposal solutions focus on reducing the risk to the UXO operator through the use of standoff and remote equipment and reduction of collateral and environmental damage by techniques other than detonation of main charges.

Each of the mission areas are working through appropriate channels on programs to provide tools and equipment to support the requirements discussed in Chapter 2. These programs are designed to provide the individual communities with equipment needed to execute its roles and missions against the current and evolving threat and selected nonmilitary requirements. Specific systems can be acquired by procurement of already developed commercial items (Non-Developmental Items (NDI)) or products from foreign sources. When this approach is not feasible, research and development is undertaken to permit acquisition of systems which will support a particular military mission. This process requires and draws upon both community-specific and DoD-wide technology base activities.

Research and development in this area is carried out using a number of different methods. The

Countermine and EOD communities utilize the formal DoD acquisition process. In addition, EOD, Humanitarian Demining, and Countermine are recognized in the Defense Technology Area Plan. The Humanitarian Demining program conducts rapid prototyping of equipment suitable for use in developing nations. In addition, the demining program leverages detection efforts ongoing in the Countermine program. The UXO Environmental Remediation community has efforts under the Strategic Environmental Research and Development Program (SERDP) and the Environmental Security Technology Certification Program (ESTCP). The active range community leverages work on-going in the other communities for use for specific range clearance efforts.

Procurement of equipment for field use is also accomplished through a variety of methods. The Army and USMC have similar Countermine missions. Each coordinates their requirements, development and procurement efforts with the other service. All four services coordinate their procurement efforts for EOD equipment. The procurement of Humanitarian Demining equipment is the responsibility of the developing nation involved in the clearance effort supported by donors such as DOS and DoD. UXO Environmental Remediation equipment is bought by the contractors who perform the work. Active Range Clearance equipment is purchased according to the needs of individual test or training programs and installations.

As resources are applied to finding solutions to the UXO problem, multiple solutions will be required for the myriad UXO types and environments that will be encountered. Different mission areas pose unique technical challenges. For example, the requirements for Countermine require speed and "weaponizing" that are not typically necessary for large scale demining operations or other mission areas. On the other hand, the criteria for Humanitarian Demining, EOD, and remediation require higher percentage clearance standards. The technologies used may be similar, if not identical, but their applications may differ by platform and conditions of use.

3.3.2 Countermine - Transitioning Technologies

The Airborne Standoff Minefield Detection System (ASTAMIDS) is managed by the Army Program Manager for Mines, Countermines and Demolition (PM-MCD). ASTAMIDS will provide the capability to detect and identify the boundaries of patterned and scatterable anti-tank mine fields such that the maneuver element commander can incorporate relevant threat minefield information into his operational planning. The following three basic operational modes have been defined for ASTAMIDS: (1) provide information for formulating the Operations Plan (OPLAN); (2) gather information used to verify or modify the OPLAN and (3) detect mines and minefields for maneuvering units to bypass or choose alternate routes to avoid minefields. ASTAMIDS will detect mines/minefields consisting of metallic and nonmetallic surface and shallow buried mines. It consists of an airborne imaging sensor (IR and/or IR laser combination) and a Minefield Detection Algorithm Processor (MIDAP). MIDAP is a high speed processor and minefield detection algorithm suite used to process sensor imagery and autonomously detect minefields. The ASTAMIDS sensor is being developed as a modular mission payload package for the Joint Tactical Unmanned Aerial Vehicle. Plans are being developed so that the sensor and processor could be mounted on a surrogate such as a manned airplane or helicopter. ASTAMIDS is scheduled to begin procurement in FY00. ASTAMIDS technology could be leveraged to other mission areas such as Humanitarian Demining, UXO Environmental Remediation, and Active Range Clearance where there are large areas to be surveyed for potential near-surface and surface UXO.

The Coastal Battlefield and Reconnaissance Analysis (COBRA) system being developed by the US Marine Corps addresses the unique requirements of standoff minefield detection associated with amphibious operations. The littoral region provides a vast array of environmental conditions that Marine Forces must traverse during an amphibious landing. These environmental conditions compound the problem of mine detection. Technologies being pursued for the COBRA system include multi-spectral, passive millimeter wave and active illumination. Technology development is included in the USMC Joint Stand-off Mine Detection Technology (Exploratory development) and COBRA ATD (Advanced Technology Demonstration). These technologies provide the greatest potential for a Littoral region mine detection capability. The IR technologies being pursued in the Army programs have showed limited capability in the Littoral region. This system is projected to begin procurement in FY03.

The Hand-held Standoff Mine Detection System (HSTAMIDS) is managed by the Army PM-MCD. HSTAMIDS will provide, for the first time, the capability to detect surface and buried metallic and nonmetallic land mines. The dismounted soldier uses a hand-held detector in those places where airborne and vehicular systems cannot operate. HSTAMIDS provides standoff mine detection of AT/AP mines for mobility and personal protection. It is intended for use by a wide range of career fields and services. The HSTAMIDS operator will lead the way for dismounted operations in areas where mines are known to exist or where the threat of mine use is high. This man-portable mine detector program is developing a standoff Infrared Thermal Imager (IRTI) and a confirming Ground Penetrating Radar (GPR) fused with a metal detector. The standoff IRTI system has a backpack that includes an image processor and batteries, an eyepiece display and 3-5m forward looking radar. The GPR/metal detector will closely resemble the configuration of the U.S. Army An/PSS-12 metal detector. HSTAMIDS is scheduled to begin procurement in FY00. HSTAMIDS technology also could be leveraged in the Humanitarian Demining mission area where surface and buried metallic and non-metallic land mines are common.

The Interim Vehicle Mounted Mine Detector (IVVMD) is managed by the PM-MCD. The Army has an urgent need for a tele-operated, vehicle-mounted, metallic and/or nonmetallic mine detection and marking system. The top priority in obtaining this capability is the development of the Ground Standoff Minefield Detection System (GSTAMIDS). Due to the anticipated fielding of GSTAMIDS after the turn of the century, there is a more immediate need for an interim GSTAMIDS capability. The IVVMD is intended to provide at least a partial GSTAMIDS capability from a non-developmental item (NDI) acquisition. IVMMD is required to detect at least metallic anti-tank (AT) mines, operate at least on-road, mark mines for follow-on mine neutralization teams, provide blast protection to the operator, and its sensor must cover at least the full width of the host vehicle. IVMMD is scheduled to begin procurement in FY98.

The Vehicular Mounted Mine Detector (VMMD) is an Advanced Technology Demonstration (ATD) program at US Army Communication and Electronics Command, Night Vision and Electronic Sensors Directorate (CECOM/NVESD). The primary operational mode of the VMMD is to detect mines on roads and routes across full vehicular widths to support commanders by keeping the lines of transportation open. There is no currently fielded vehicular mounted system that can detect both metallic and nonmetallic mines. The ATD will demonstrate in FY98 a system using a multiple sensor suites, sensor fusion and automatic target recognition techniques. Sensor fusion will provide for a higher mine detection rate while keeping false alarm rates at an acceptable level. The sensors that will be demonstrated include IR, GPR, and electromagnetic induction detectors. The IR sensors include both 3-5μ and 8-12μ wavelength sensors. These will be currently available sensors with specially developed

automatic target recognition algorithms. The primary purpose of the IR is to provide a standoff cueing detection capability. The GPR approaches operate in the 13GHz band which represents a tradeoff between the lower frequencies required for sufficient ground penetration, and the higher frequencies which are needed to achieve high spatial resolution of suspected targets. Various algorithm approaches are being investigated for use with the GPR approaches. The electromagnetic induction detection combines traditional metallic mine detection operating feature with an innovative concept that combines the induction coils with the GPR antennas into a single search head. The program is scheduled to transition to the PM-MCD in FY98, where it becomes GSTAMIDS. Procurement is to begin in FY02.

The Mine Hunter/Killer (MH/K) is an Advanced Technology Demonstration (ATD) program at CECOM/NVESD. The MH/K program will allow the Army to investigate and clear routes and roads through terrain where conventional Countermine tools are not desirable and to do so at near tactical speeds. The purpose of the MH/K program is to develop an integrated standoff mine detection and neutralization system for installation on any tactical vehicle. The system is intended to neutralize surface laid and buried, metallic and nonmetallic, AT and large AP mines. The MH/K system will consist of a multimode sensor array including forward looking radar, and FLIR systems with a robust sensor fusion architecture and advanced automatic target recognition (ATR) algorithm suite, a target designation system, a set of anti-mine weapons with computer fire control and articulation, a stabilized tele-operations kit. The system will detect and destroy mines and unexploded ordnance in a wide path in front of the vehicle at near tactical speeds without needing to pause or stop. The ATD will be conducted in FY00 and transition to PM-MCD in FY01.

The Advanced Mine Detection Sensors is a CECOM/NVESD 6.2 basic research effort to evaluate enhancements to forward looking radar and investigate other promising standoff detection technologies against AT and AP mines. This effort will demonstrate potential payoffs for increased standoff detection in all weather conditions using advanced sensors and acoustic and seismic technologies as an additional means of enhancing the performance of all ground based detection systems. In FY00, this program will integrate these technologies onto a surrogate ground-based platform and demonstrate multi-sensor ability to detect mines remotely at speeds of 5-20 Km-hr. In FY01, CECOM/NVESD will conduct an ATD for advanced mine detection sensors for detection of AP mines. This will provide the Army with enhanced forward looking radar for greater standoff and all weather detection. This will provide the forces with greater survivability and lethality in all weather and terrain conditions. The technologies which increase the standoff detection with low false alarm rates will be product improvements to the GSTAMID and MH/K systems.

The Lightweight, Airborne Multi-Spectral Countermine Detection System (LAMS) is CECOM/NVESD effort beginning in FY98. The program will explore innovative concepts and technologies to support a lightweight airborne standoff mine detection capability. This will provide the maneuver commander with the capability to detect limited area, limited corridor route reconnaissance and detection of nuisance mines along roads. This program will investigate a variety of new component and focal plane array technologies such as 3-5μ staring focal plane array, multi/hyperspectral, passive polarization, active sources and electronic stabilization to support a lightweight, limited capability for future tactical unmanned aerial vehicle. An ATD is planned for FY01. This program will transition to PM-MCD in FY02.

The Grizzly, an M1 tank chassis-based system, is managed by the Army Program Manager, Combat Mobility Systems. The Grizzly provides an in-stride capability to breach complex obstacles of mines, wire, posts, rubble, and ditches to create a lane for other vehicles to follow. It will be employed as an

integral part of the M1/M2 equipped maneuver task force, the Grizzly supported by friendly direct and indirect fire, will lead the maneuver force through obstacles with minimal preparation and with little or no loss of momentum. The Grizzly's primary features are a full-vehicle-width mine-clearing blade and a powered arm mounted on an M1 chassis. It will mount a machine gun and Mk19 40mm grenade machine gun (or equivalent) for self defense. Through future improvements, it will be capable of accepting other mine detection and Countermine device. The Grizzly will have mobility and survivability characteristics comparable with the M1 series Abrams tank. The Grizzly is scheduled to begin procurement in FY02.

The Explosive Standoff Minefield Breacher (ESMB) is managed by Program Manager for Mines, Countermine and Demolitions (PM-MCD). The ESMB is a device either mounted on a dedicated vehicle or towed behind designated vehicles. It will replace the Mine Clearing Line Charge as a device to breach mines. It will neutralize (by detonation, deflagration, or physical removal) all on- and off-route mines. The ESMB is scheduled to begin procurement in FY02.

The Anti-Personnel Obstacle Breaching System (APOBS) is a joint 6.4 program being managed by the Marine Corps' Program Manager for Engineer Systems (PM-ES) and the Army's Project Manager for Mines, Countermine, and Demolitions (PM-MCD) with technical support from NVESD. The APOBS will produce a 0.6 m wide by 45 m long breach through wire obstacles and blast hardened APL. APOBS consists of grenades spaced along detonation cord. It will replace the Bangalore Torpedo reducing the time to create a breach from 240 man minutes to less than 4 man minutes, reducing the weight of materiel consumed from 560 Kg to 57 Kg and providing a 35 meter standoff enhancing soldier survivability. The system will soon be type classified with production to begin in FY 98 and First Unit Equipped (FUE) will occur in FY 01.

The Assault Breach Marking System (ABMS) is managed by Program Manager for Mines, Countermine and Demolitions (PM-MCD). The ABMS is the vehicle mounted replacement for the Cleared Lane Marking System (CLAMS), the original mounted marking system for The BCIS, which proved ineffective during Desert Storm. This is a Non-Developmental Item (NDI) effort with improved visibility over CLAMS, and provides reusable components during training. This effort will begin procurement in FY00.

The following chart depicts the expected first year of procurement (PROC) and first unit equipped (FUE) date for each of these developmental systems.

Table 3.2 Countermine Procurement and Fielding

	98	99	00	01	02	03	04	05	06
ASTAMIDS			PROC		FUE				
COBRA						PROC		FUE	
HSTAMIDS			PROC		FUE				
IVMMD	PROC		FUE						
GSTAMIDS					PROC		FUE		
GRIZZLY					PROC		FUE		
ESMB					PROC		FUE		
ABMS			PROC		FUE				
APOBS	PROC			FUE					

FUE: First Unit Equipped
PROC: Procurement

3.3.3 EOD - Transitioning Technologies

The Explosive Ordnance Disposal /Low Intensity Conflict (EOD/LIC) program, a 6.3 rapid prototyping and Advanced Technology Demonstration program, has developed the hand-held Automated Ferrous Locator which combines a highly accurate acoustic navigation system with a conventional ferrous locator. This system allows automated correlation of total magnetic field data with geographic position leading to the rapid construction of a magnetic anomaly map after the operator sweeps over the area of interest. This system will transition to the Advanced Ordnance Locator (AOL) acquisition program sponsored by PMS-EOD.

EOD/LIC is currently funding the development of the Imaging Ordnance Locator which is a forward looking, ground penetrating radar designed to detect and classify small, shallow buried targets. The primary purpose of this project is to put some distance between the system operator and a potentially dangerous ordnance item. A prototype system will be available for testing by the Summer of 1997.

The Joint Service EOD applied research program is investigating two sensor approaches for improving the detection capabilities of the AOL. The first is a five axis Superconducting Quantum Interference Device (SQUID). The use of five axis will allow the measurement of magnitude and x, y, z and dipole orientation. The use of the SQUID reduces the distance between elements and eliminates flexure and, therefore errors, in a gradiometer. This effort will end in FY99. The second sensor technology also looks at multi-axis sensors but will focus on an active inductance method. A Time Domain Electro-Magnetic (TDEM) approach will be used where the normal sampling of a single point on the time decay curve will be replaced with multiple time gates. The method can be used to recover phase information from the target and allow discrimination. This effort will end in FY99. Both of these efforts are aimed at providing technologies for hand held systems.

PMS-EOD has just received Milestone III approval for production of the Remote Controlled Reconnaissance Monitor (RECORM). RECORM is a remotely operated vehicle that provides a visual method of detecting and identifying surface ordnance that primarily supports the Army doctrine to first use a robotic vehicle in place of an EOD operator. RECORM is a 110 pound vehicle that provides a 650 meter standoff capability to inspect unknown UXO items through the use of a color or low light black and white camera.

The NAVEODTECHDIV is developing Autonomous RECORM (Auto-RECORM) which is a modification of the existing platform that will provide autonomous control, obstacle avoidance and mapping of an area containing surface UXO. Once a target is identified by visual means the target is compared to the AEODPS database of images to provide a probable ordnance match. This data is then downloaded to a number of distributed robots that will reacquire and remove the UXO. This effort will end in FY98 and transition to a Joint Robotics Program for the Basic UXO Gathering System (BUGS).

The EOD/LIC Standoff Dearmer with Laser Sight Project is adding laser aiming devices to EOD explosive dearmers and evaluating the system accuracy for standoff disruption. EOD teams operating in Bosnia have found that current EOD tools do not allow for disruption of booby traps in confined areas. This development will transition to the Standoff Disrupter acquisition program in FY98, which will provide an explosively driven, slug firing device for disrupting the booby trap and fuzing mechanisms form a standoff distance. A Milestone III decision is planned for FY00.

Army EOD has begun investigation of an Advanced EOD Bomb Suit. The Army's Natick Laboratory will study materials and suit design to reduce weight and bulkiness of bomb suits. A prototype suit will be designed and tested. The task will be completed in FY99.

EOD/LIC is in the process of initiating a rapid prototyping effort for case entry of thick walled UXO. A portable abrasive waterjet cutting system with remote capability is envisioned using slurry jet technology.

Technologies for allowing access through electronic booby traps are under development in the Joint Service EOD applied research program in the Electronic Safe and Armed Fuze (ESAF) Monitor and Sensor Defeat Tools tasks. The ESAF monitor investigates methods for determining the status of electronic fuzes in order for the EOD technician to understand handling hazards. Both passive and stimulated emissions are being studied. This effort will be completed in FY98 and transition to a PMS-EOD effort. The sensor defeat tools effort is also investigating passive and active means to allow the EOD technician to operate in an area that contains electronic booby trap sensors. This effort will be completed in FY98.

PMS-EOD is upgrading the capabilities of the MK-32 x-ray system in the Advanced Radiographic System (ARS). ARS provides a digital data acquisition capability to replace the use of x-ray film. This will allow the EOD technician to capture the x-ray image from a remote location and use image processing algorithms to enhance the image. This effort is a non-developmental item (NDI) scheduled for Milestone III in FY99. The Office of Special Technologies is funding a three dimensional visualization effort to extend the ARS capability to provide rendering of internal components. This effort will be completed in FY98.

PMS-EOD is developing the Remote Ordnance Neutralization System (RONS) to upgrade the RCT capabilities to neutralize UXO in field environments. The RONS will provide the EOD technician with a

capability to perform limited procedures from a 650 meter standoff distance. RCT will be improved with a faster track system, more degrees of freedom in the manipulator and extended standoff distance. The Milestone III for this effort is scheduled for FY99. The Joint Service EOD applied research program is also investigating technologies to reduce the cost and increase the capabilities of remote manipulators. The Serpentine Manipulator task is exploring the use of multi-segmented manipulators to increase dexterity of small robotic arms. Precise control of a multi-segmented, one meter arm will allow a robotic system to operate in the interior of a UXO item. This effort will be completed in FY97. The other effort is the replacement of electric or hydraulic actuators by a polymer muscle technique. Current electrical actuators do not have a sufficient output to weight ratio to be effective in small robotic systems. Hydraulic systems are effective but require the use of a pump in the system design. Electro-strictive polymer offer the possibility of converting electrical input into high force motion. This effort will be completed in FY99.

The Joint Service EOD applied research program is investigating two approaches to providing a remote capability to clear areas of large quantities of surface UXO. The first is a the high power laser diode program. This effort is developing a laser diode to enable the development of a HMMWV Laser Ordnance Neutralization System (HLONS). A 1000 watt Nd:YAG laser is used to cause low order reactions in surface munitions. A prototype system will be constructed and tested in FY98. The second effort develops robotics control approaches for multiple low cost robotic vehicles. This effort supports the BUGS concept of using many low cost ($1000) autonomous robots to pick up and carry away (PUCA) or blow in place (BIP) surface submunitions. A final test of a multiple vehicle control system is scheduled for FY99. The BUGS program will start in FY98 to begin integrating target identification and location information from a sensor platform, Auto-RECORM, with multiple small vehicles to perform the PUCA or BIP functions.

PMS-EOD is developing two explosive hand tools for rendering safe UXO. The Lightweight Disposable Disrupter System (LIDDS) for use in areas with large numbers of UXO. The current MK 2 disrupter is a heavy system that damages the fuzing mechanism of a UXO. The procedure requires the operator to recover the system components after each firing. Only one or two MK2 can be carried by each EOD technician. The LIDDS will provide a low cost, one shot alternative to the MK2 for areas with large numbers of UXO. LIDDS will reach a Milestone III decision in FY99. The Main Charge Disrupter (MCD) is for use when the fuzing mechanism can not be reached. The MCD will cause a reliable low order reaction in large UXO items to mitigate collateral damage by firing a shaped charge into the main high explosive charge of the UXO item. MCD is a non-developmental item that will reach Milestone III in FY99.

Table 3.3 EOD Procurement and Fielding

	98	99	00	01	02	03	04	05	06
AOL							PROC		FUE
RECORM	PROC		FUE						
BUGS							PROC		FUE
ARS		PROC	FUE						
RONS			PROC	FUE					
LIDDS			PROC	FUE					
MCD			PROC	FUE					

FUE: First Unit Equipped
PROC: Procurement

3.3.4 Humanitarian Demining - Transitioning Technologies

The U.S. Army CECOM Night Vision and Electronic Sensors Directorate (NVESD) has been selected by the Office of the Assistant Secretary of Defense for Special Operations and Low Intensity Conflict, ASD (SO/LIC), to develop and demonstrate innovative advanced technologies for mine detection, mine clearance, protection of deminers, and training which have application to Humanitarian Demining operations. NVESD issued a Broad Agency Announcement (BAA) for the purpose of soliciting proposals for technologies which offer the means for detecting and clearing mined areas in Humanitarian Demining operations.

The Humanitarian Demining program objective in the detection technology area is to adapt commercial-off-the-shelf (COTS) equipment and, when available, leverage mature technology from Countermine and other government agencies. The 1997 Humanitarian Demining Technology Program is considering proposals that address requirements in hand-held, vehicle based, and wide area mine detection areas as well as continuing the development of high potential developments from previous years. These technologies will be developed, demonstrated, and transitioned to the international demining community in 10 to 14 months.

As part of the FY97 program, high emphasis is being placed on being able to transition items developed in-house by the government to industry vendors. Several high potential items (mine rake, berm processing assembly, long reach weed eaters, improved mini-flails, multi-tined rollers and heavy grapnel) have been turned over to industry for design finalization and possible production.

High potential items will be evaluated in actual mined areas as part of the U.S. demining training and support missions. Additionally, NVESD will prepare a catalog containing known and evaluated equipment ready for acquisition by both government and non-government organizations. Vendor information as well as points of contact in the government will be made part of the catalog.

The Humanitarian Demining program objective in the clearance technology area is to adapt, when possible, COTS equipment while leveraging mature technology from Countermine and other government organizations. The 1997 Humanitarian Demining technology program is also considering proposals that address requirements in large area clearance and mine neutralization. These technologies will be developed, demonstrated, and transitioned to international demining environments in 10 to 14 months.

The Humanitarian Demining technology program is investing in four technology developments in large area clearance: (1) the Mine Rake and the Mine Clearing Blade are mechanical systems that are integrated onto commercial bulldozers. These devices remove mines buried up to 10 inches by sifting the soil and exposing the mines for subsequent neutralization; (2) the Berm Processing Assembly (BPA) is a system that is usually towed behind a large area clearance vehicle (bulldozer) to remove mines from the earthen berm that is created by the clearance device. The BPA picks up the dirt and applies a mechanical filtering process that deposits the mines on top of the berm for subsequent neutralization; (3) the Tele-operated Ordnance Disposal System (TODS) adds a mechanical clearance capability to an off-the-shelf skid steer loader chassis. TODS utilizes individual attachments to remotely excavate individual mines; and (4) the Multi-Tined Roller for on/off route detonation of antipersonnel mines, while not activating the anti-tank mines.

3.3.5 Active Range Clearance - Transitioning Technologies

The Air Force Wright Laboratory is developing the Surface Munitions Clearance Vehicle (SMCV), a tele-operated commercial tractor fitted with an armor package, remote controls, and a "windrow" pushing blade to clear paths through fields of cluster bomb units (CBU) on flat CBU training ranges. The SMCV provides safe paths for EOD technicians to move through the CBU field and facilitates disposal of remaining CBU. In addition, a robotics fine-manipulation arm and shallow ordnance excavation tools are being developed and tested for ordnance recovery. Demonstration of the "windrow" capability was accomplished in FY 97.

Commercial rock crushers are being demonstrated as a potential means for eliminating some of the problems associated with certifying range residue. Currently, EOD technicians perform visual inspections of range residue to ensure it does not contain live spotting charges. By crushing practice bombs into pieces, a commercially available rock crusher can be used to guarantee that the resultant residue contains no live spotting charges. This approach offers significant advantages over visual inspections: the likelihood of accidents is lower, the integrity of certification process is higher, and the resultant residue is more marketable for recycling purposes.

3.3.6 Environmental UXO Remediation - Transitioning Technologies

The Department of Defense has undertaken efforts to identify, demonstrate, and transition new technologies for UXO Environmental Remediation. The technical challenge to discriminate between UXO and non-hazardous clutter requires investment in research development of new technologies.

Demonstration of systems to support the needs of the site remediation community has been the focus of two efforts: the Environmental Security Technology Certification Program (ESTCP) and the Congressionally mandated Advanced Technology Demonstrations at Jefferson Proving Grounds (JPG).

Due to congressional interest, a series of Advanced Technology Demonstrations (ATDs) have been conducted at Jefferson Proving Ground (JPG) and at four other sites (Yuma Proving Ground, Fort

Jackson, Eglin Air Force Base, McChord Air Force Base). The demonstrations were to identify and evaluate the performance of commercially available technology. To date, over 60 UXO detection and excavation systems have been demonstrated and evaluated. A technology performance baseline has been established. Some systems have demonstrated a detection rate approaching 95% but high false alarm rates and less than desirable discrimination capabilities between UXO and non-hazardous clutter detract from overall system performance. Demonstrations of airborne technology indicate little or no current ability for UXO detection. Remote excavation systems evaluated in these demonstrations still require improvement in excavation speed and cost.

The ATD Program funded demonstrations of commercially available technology. As a consequence of the demonstrations, private industry gained a quantitative understanding of the technology capabilities of their system in a field environment. These demonstrations highlight areas for further exploration and technology enhancement.

The ESTCP has funded a small number of demonstration efforts designed to: 1) provide technical information to understand limitations of current technologies, 2) examine Countermine technology with potential application to subsurface UXO characterization, and 3) transition successful new technologies to the user community. Three efforts are being completed this year. These projects are funded on a year-to-year basis.

The Multi-Sensor Towed Array Detection System (MTADS) provides an operator driven capability to survey large areas. MTADS is a vehicle towed system which employs arrays of state of the art commercially available magnetic and pulsed induction sensors integrated to allow the user to see through near-surface clutter and optimally detect targets and automatically determine size and location. High precision Differential GPS is used with target matching algorithms to generate precise maps of ordnance location. This system has completed demonstration/validation testing and will be operationally used at a live ordnance site this year.

An airborne active laser and passive laser/IR system, developed originally for Countermine activity is being tested for surface detection of UXO found on US ranges and Formerly Used Defense Sites (FUDS). The system is flown aboard a Black Hawk helicopter, and offers the capability for broad area searches of potentially contaminated lands. Large areas can not be cost effectively surveyed using current manual approaches. Using the thermal signature and reflectance properties of UXO, large areas can be rapidly and safely surveyed.

A remotely controlled system designed to detect and discriminate near surface ordnance from non-ordnance metallic clutter is being evaluated. The two sensors operate in a target cueing method in which an induction metal detector rapidly detects all near surface suspicious targets. The secondary sensor is a Thermal Neutron Activation (TNA) sensor which confirms whether the target is ordnance by detecting high concentration of Nitrogen. Follow on work to extend the detection capability of the TNA sensor is planned.

These tests will determine the current potential of these technologies for UXO Environmental Remediation and assess the underlying limits of the technology and potential for improvements. Successful technologies are rapidly transitioned and the test data exploited by the development community for future improvements. Future work is planned to further enhance these systems and test and transition new sensors, algorithms, and data fusion approaches currently being developed.

Development work in support of environmental UXO remediation is being conducted by the Army and the Strategic Environmental Research and Development Program (SERDP). The SERDP has programmed a new effort for the development of detection technologies for environmental remediation. SERDP plans to invest an additional $15 million over 5 years. This investment plan emphasizes research and development to understand the physics phenomena and process impacting UXO detection and discrimination.

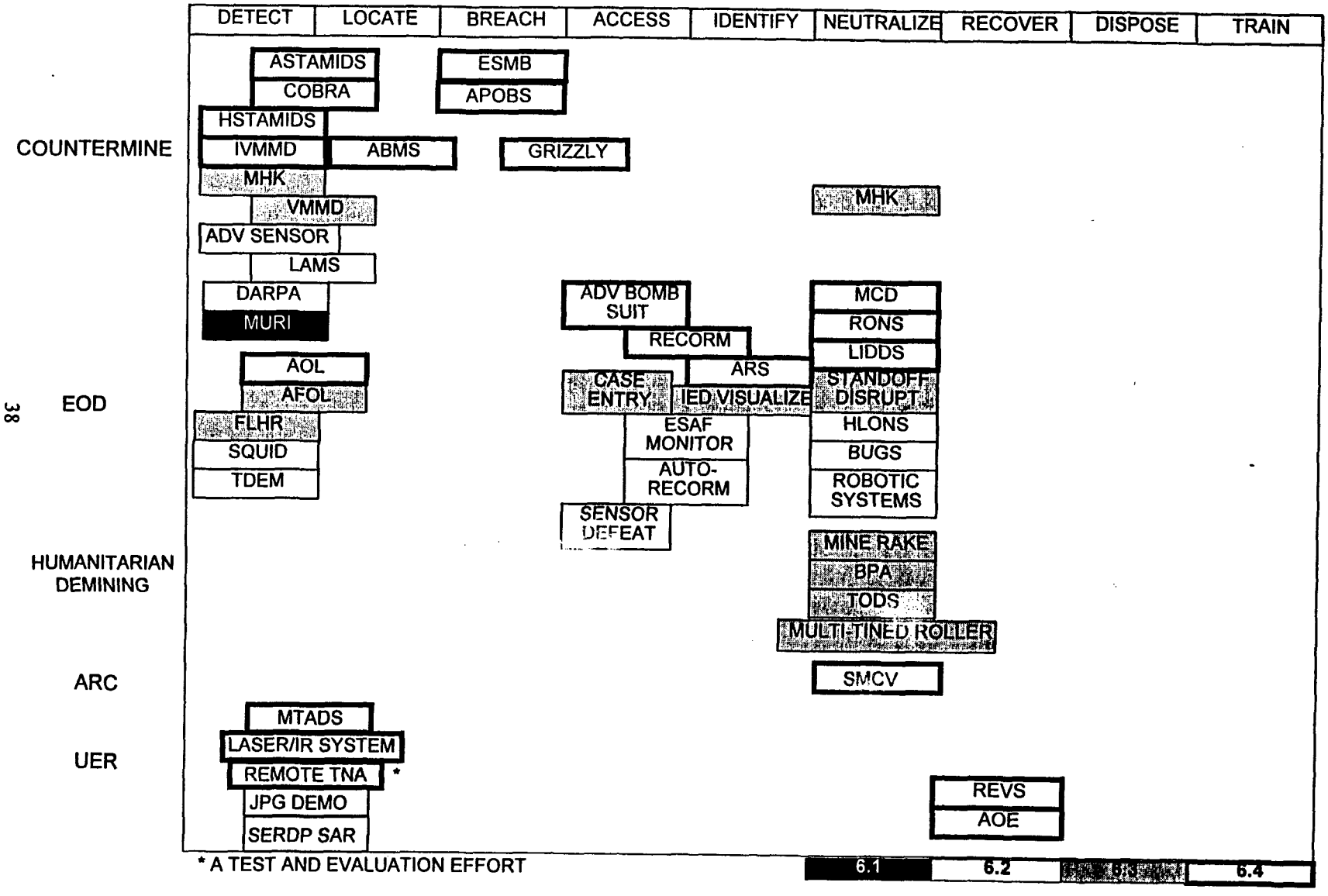
This work will directly assist in developing the understanding between sensor performance for detection and discrimination of UXO. Research on systems incorporating acoustic, magnetic, inductance, and radar sensors are being examined. Efforts currently underway include a multi-sensor data fusion program, a low frequency ultra-wide band synthetic aperture radar (SAR), and impulse third harmonic radar.

3.4 Summary of Evaluation

The current capabilities and technologies in UXO detection and neutralization were compared to the list of requirements to determine if existing programs could be leveraged by other communities. The intent was to insure full utilization of available resources to the benefit of all mission areas. Further, this evaluation could determine if the perception of duplicate efforts was founded. Appendix G provides an in-depth analysis of the applicability of each of the development efforts discussed in section 3.3 to the needs identified in section 2.4.

Table 3.4 provides a graphical representation of all the development efforts funded in fiscal year 1997 and planned in fiscal year 1998 to support UXO mission area requirements. The efforts for each mission area are charted by UXO functional area to provide a means for identifying areas where multiple efforts are planned or underway. The efforts are also keyed to show the maturity of development for each effort based on the DoD research phases. Each of these efforts is matched to at least one requirement listed in section 2.4. A listing of each requirement and the applicable development effort is shown in Appendix G. Each of these efforts is described in detail in the UXO Database on an individual data entry sheet. The two technology subgroups have discussed each of these efforts to understand the differences and the potential for leveraging of the underlying technologies in each effort.

Table 3.4 UXO Developmental Efforts



Review of the efforts shown in Table 3.4 identified two functional areas where perception of duplication and potential for leveraging were apparent: detection and neutralization. This was not unpredictable since these are the two most important functions in any UXO clearance operation. The subgroups discussed the efforts in these two functional areas and found no basis for the perceived duplication of effort. The subgroups also identified areas for leveraging technology. The areas identified are discussed in the following paragraphs.

3.4.1 Countermine

A majority of the Countermine efforts address detection and location of anti-tank and anti-personnel mines from three types of platforms: airborne, vehicle and operators. The 6.4 efforts focus on enhancing capabilities on each of these platforms to support combat operations. The airborne systems focus on locating minefields and may progress to the state of providing a wide area surface UXO density measurement. The vehicle systems will provide a capability to clear on-road anti-tank mines with forward looking sensors. Hand-held development focuses on providing a capability to detect shallow buried low and no metal mines immediately to an operator. The hazard associated with mines requires that the operator be cognizant at all times of detector output and make the final decision on the classification for mine like or not mine like target. All of these developments concentrate on technologies for detecting surface and shallow buried low metallic targets. Leveraging of these technologies by other missions areas will allow the other areas to focus on larger, metallic more deeply buried targets. The 6.3 efforts and advanced sensor 6.2 effort in Countermine will extend the capability to detect and classify shallow buried targets in front of a moving vehicle. The applicability of these techniques must be studied by the other mission areas to determine if the cost associated with rapidly searching and detecting shallow buried targets is warranted for their needs.

The DARPA explosive detection and MURI shallow buried target detection efforts have potential payoffs for all the mission areas. The detection representatives for each of the UXO mission areas will work with the DARPA and MURI program managers to leverage these investments.

The MHK kinetic energy kill concept currently under investigation, a 25mm cannon (or other ballistic solution) with an advanced fire control, has applicability to the need to rapidly clear surface munitions. Researchers for this effort and the EOD HLONS effort have agreed to define a common set of targets and report the advantages of kinetic energy versus laser energy kill mechanisms for both mines and small surface UXO.

3.4.2 EOD

EOD efforts in detection focus on hand held systems that can be used to survey an area for buried metallic UXO. The information gathered by the systems can be stored and post processed to classify anomalies as UXO or non-UXO. The threats in this case can be buried anywhere from a few inches to 30 feet in depth and have metallic content ranging from grams to hundreds of pounds. Accurate location of the UXO in x, y and z planes is required to plan the access, neutralization, recovery and disposal functions. The 6.4 effort in this area supports the combining of a multi-axis magnetometer/active inductance locator with a differential global positioning system to provide plots of areas containing UXO. The 6.2 and 6.3 efforts are focusing on the development of the multi-axis sensors and development of the data gathering equipment.

In the neutralization area the focus is providing remote, standoff and hand-held techniques for rendering safe or low order detonating UXO. Development of hand-tools is a unique EOD function that may have applicability to Humanitarian Demining, Active Range Clearance and UXO Environmental Remediation. The HLONS standoff laser technique is similar to the MHK disruption requirement and the two efforts will be closely coordinated. The remote efforts in EOD focus on providing robotic agents that can duplicate discrete tasks that are high risk to EOD operators. The robots must be able to accomplish high risk missions utilizing advanced manipulation capabilities or special tools and must be small enough for a field EOD unit to transport and use in both interior and exterior environments. This eliminates the possibility of large remote excavation equipment or medium size systems that use an internal combustion engine for power. The effectors must be able to perform multiple operations for render safe procedures.

3.4.3 Humanitarian Demining

The Humanitarian Demining efforts focus on using remote equipment to move or dig up land mines. Several of these efforts require a large bulldozer with special mechanical attachments while another effort uses a skid steer loader with a small backhoe. This equipment is primarily of use in a non-combat environment for shallow buried targets. This technology may be leveraged to other areas, particularly it may be applicable to Active Range Clearance.

3.4.4 Active Range Clearance

The only active effort in this area utilizes an all terrain remote robot to sweep surface submunitions from flat, open areas. The sweeper has EOD, demining and range remediation applications in limited areas.

3.4.5 UXO Environmental Remediation

The UXO Environmental Remediation community has invested in understanding the relative performance of commercial-off-the-shelf detection equipment on airborne, vehicle mounted and hand-held platforms to detect, classify and map buried ordnance over large areas. The information from this testing can be used by other communities to understand the relative performance of different sensor types for their specific applications. The SERDP will focus on the development and integration of novel sensing technologies for enhanced detection, location and discrimination of buried UXO under a wide range of environmental conditions.

3.5 A Technical Overview of UXO Detection and Disposal

The detection of Unexploded Ordnance is a complex technical problem because of the wide variety of types of munitions and fuzing and because of the varying conditions of terrain, climate and operating environments in which they are found. Also, in every case it is a life and death matter for the operator of detection equipment. Faulty or unreliable equipment, inadequate training, elevated expectations or overconfidence can all be fatal to an operator. The needs to detect buried UXO more efficiently and rapidly and to clear large areas in a rapid and safe manner call for more advanced technical solutions. Our intent is to provide equipment that minimizes the hazard and the risks associated with this dangerous business.

This section provides a brief technical overview of some of the technologies associated with UXO detection. These technologies are applicable to all five UXO Mission Areas. Technology is the common denominator. What we learn about detection for Countermine operations and Humanitarian Demining often has direct relevance to problems in EOD, Active Range Clearance, and UXO Environmental Remediation.

Table 3-5 summarizes some of the operational characteristics for each of the mission areas such as ease of use by the operator, versatility and usefulness under a variety of conditions and the degree to which a system must be militarized for use under more demanding operating conditions.

Table 3.5 UXO Clearance – Operational Characteristics (by Mission Area)

	Mission Areas				
Operational Characteristics	Countermine	EOD	Humanitarian Demining	UXO Environmental Remediation	Active Range Clearance
• Effectiveness	<100%	~100%	~100%	~100%	~100%
• Speed	Critical (maneuver force dependent)	Critical (Location dependent)	Non-critical	Non-critical	Non-critical
• Ease of use (Training Required)	Complex	Complex	Simple	Complex	Complex
• Versatility	High	High	Low	High	High
• Size/weight	Critical	Critical (Mission Dependent)	Not critical	Not critical	Not critical
• Maturity	High(rugged)	High(rugged)	COTS	COTS	COTS
• Permission for Technology Transfer	Not Required	Not Required	Required	Not Required	Not Required
• Cost	User driven	User driven	Host Nation affordable	User driven	User driven
• Casualties	UXO and Direct & Indirect fires	UXO	UXO*	UXO	UXO

*NOTE: US provides training and equipment support only.

3.5.1 Metrics for Success

Although there are many requirements, boundary conditions, and secondary requirements associated with each of the five mission areas, the metrics tend to be constant. Simply stated, the success of UXO clearance operations can be measured by the time it takes to clear an area to the level of confidence commensurate with the mission. The measures of performance are:

- Probability of detection. This measures the percentage of objects detected out of those known or expected to be present.

- Probability of false alarm. This measures the percentage of false detections per unit area. Plotted with the probability of detection, the two provide the receiver operating characteristic curve (ROC). When the false alarm rate (FAR) becomes too high, the detection process degrades to guessing.

- Probability of classification. The ability to classify the item as UXO and preferably category (bomb, mortar round, mine) will greatly influence the ability to clear.

- Clearance rate. The area treated per unit time. For example, in the case of mapping minefields for the countermine mission, the number of square kilometers mapped per hour is the measure of performance.

Some systems provide very high confidence but at unacceptably low rates of area coverage. Others provide less confidence at much higher rates. At the present, airborne systems have been successful in delineating minefields. Conversely, a ground sensor may be able to identify and map individual UXO items, but is only able to do so at 0.5 km/hr along a narrow road.

At first glance, Table 3.5 could be interpreted to imply that the operational characteristics are too diverse and that no underlying performance regimes exist to satisfy the various missions. The time scales of the missions vary from minutes to years, and the area covered can range from a few tens of square meters to hundreds of square kilometers or more. In fact, there are some basic themes that apply:

- All missions seek 100% detection rates.

- All would prefer no false alarm rates.

- All want to classify the targets.

- All want high speed with no sacrifice of the above.

There are underlying similarities in the physics to attain these capabilities. This characteristic makes detection technology a common denominator for all mission areas.

3.5.2 Principles of Detection

Detecting a UXO involves the use of sensors that sense the object itself and/or its effects on its surroundings. For example, a metal mine may be sensed directly by its magnetic signature as detected by a magnetometer. On the other hand, a thermal imaging sensor cannot see a recently buried mine, but may sense the thermal signature of the disturbed soil covering the mine. Chemical sensors may detect the presence of explosives on, adjacent to, or in the general vicinity of the ordnance.

A discussion of the performance of any detection technique must include the detection capability of the sensor, the false alarm rate, and the ability to classify targets. In case of mine or UXO detection, the fundamental limitation of current technologies is the false alarm rate. Many sensors are capable of producing a measurable signal for a mine or a UXO; however, using current techniques, the signature of the target is not clearly distinguishable from other non-hazardous items. Today, even at modest detection probabilities, the false alarm rates for single sensors against difficult UXO are often too high.

In these difficult cases, two or more sensors may be required to increase confidence, i.e. to determine conclusively that the detection is real rather than a false alarm. The price of a false alarm is that some additional resource must be expended to investigate the alarm and determine whether it is a threat. If the false alarm rate is too high, the user may suffer unacceptable cost or failure of the mission.

3.5.3 Sensor Technology

There are many sensor technologies that can be used to find UXO. They all have their advantages and shortcomings. The following identifies some of the better known sensor technologies.

- Metal Detectors. Pulse induction detectors are well suited to detect metal objects, i.e., mines. Magnetometers and gradiometers are used to measure a disturbance in the earth's magnetic field. These devices will detect a majority of UXO items but have no capability to detect mines and other small UXO that do not contain ferrous metals.

- Ground Penetrating Radar (GPR). GPR covers a broad range of techniques for transmitting electromagnetic energy and receiving a reflected return from a UXO item. Depending on the soil properties, GPR at frequencies of 5 GHz or lower can provide useful signatures at soil depths of up to one foot. Lower frequencies penetrate deeper but require more processing to provide resolution. This technology is very useful against metal and plastic mines.

- Electro-Optical/Thermal Imaging. The use of imaging techniques outside the band of human perception provides visual clues to the operator on the presence of buried UXO. Operates in the 3-5 or 8-12 micron spectra, and provides high resolution images suitable for recognizing ordnance by its shape and detailed features. May be used in air and ground platforms, against fields or single objects. Detection relies not on soil penetration capability but on the ability to sense buried objects due to the temperature difference of the disturbed soil. Hyperspectral imaging senses detailed color spectra of the object and its surroundings. It is applicable to all optical regions of the spectrum from ultraviolet out to the far infrared. Exact region and number of bands depends on application.

- Synthetic Aperture Radar. Provides 2-D image with resolution sufficient to recognize the shape of antitank mines and larger objects. Depending on frequency, some soil penetration is possible. This sensor may only be used from the air and is best suited to detecting minefields rather than individual ordnance. Best against metal objects.

- Bulk Chemical Detectors. Bulk detectors measure the resultant response from the interaction of electromagnetic energy with the chemical constituents of explosives. X-ray backscatter techniques use an x-ray source. The backscatter (reflection) of the x-rays is a measure of the presence of anomalous quantities of low atomic number material (carbon, hydrogen, nitrogen, oxygen). Backscatter techniques are limited in that they would not make the distinction between ordnance and benign materials such as a block of plastic. Neutron techniques use either electronic or isotopic sources. These techniques rely on detection of the resultant interactions of high energy neutrons with elemental explosive constituents such as nitrogen or hydrogen. Attenuation by surrounding material is the major limiting factor for neutron techniques. Nuclear quadrupole resonance an RF signal to alter the alignment of nuclei in crystalline material. The frequency by which alignment change occurs is

dependent upon the type of material. When the signal is removed the resulting response can be measured from the nuclei returning to their original position.

- Trace Chemical Detectors. Trace detectors are passive devices that rely on an explosive signal to be released from the UXO item. Capability to detect is limited by the transport mechanism of the explosive signal to the detector from a buried item. False alarm rates will be determined by the local conditions. If the environment has been contaminated with explosive residue, false alarm rates will be high. These detectors have no capability to classify targets.

- Biological Detectors. The most effective biological sensor for the detection of UXO is a trained canine. This semi-autonomous, high mobility platform housing multiple sensors and a million year old trained neural net has demonstrated high detection rates for shallow buried UXO and other explosive devices with low false alarm rates. At the other end of the spectrum are nitrogen sensing microorganisms that can detect the presence of explosives.

3.5.4 Automatic Target Recognition (ATR)

Future sensors will provide better discrimination, reduce P_{fa} and sidestep the issue of user fatigue by incorporating ATR software. Although humans can be trained to interpret information from many sources, some of the more useful UXO sensors being considered produce signatures that are unfamiliar and difficult to adapt to. For example, GPR produces a "squiggly line" rather than an image to the operator. ATR software can easily interpret such signatures, whereas the human is unprepared for such data. ATR can also be used to fuse information from multiple sensors. The ATR would be used to aid human performance.

3.5.5 Systems of Systems

No single technology "Silver Bullet" exists which will solve the UXO clearance problem. Discrete partial solutions exist for very narrowly defined missions. A "system of systems" approach that uses the complementary capabilities of a variety of systems is needed in each of the five mission areas. The tool box for each mission area will be different in order to address the differences in threat or the conditions of its use. Sensor fusion, signal processing and automatic target recognition (ATR) will provide the most effective solution set to achieve acceptable probability of detection and reduced false alarm rates in all of these mission areas. Table 3.6, depicts selected near-term technology opportunities and the systems, programs or research efforts to which they are expected to apply.

Table 3.6 Near and Mid Term Systems/Programs – A Representative Example

	Near and Mid - Term Systems/Programs																
Technology	ASTAMIDS	COBRA	HSTAMIDS	IVMMD	GSTAMIDS	Grizzly	ESMB	ABMS	AOL	RECORM	BUGS	Standoff Disruptor	ARS	RONS	HLONS	LIDDS	MCD
Infrared	●	●	●		●												
Active Laser	●														●		
Automatic Target Recognition	●		●		●												
Ground Penetrating Radar			●		●												
Metal Detection			●	●	●												
Mechanical (Rollers)				●													
Mechanical (Full-width Blade)						●											
Rocket Emplaced Explosive Charge							●										
Pneumatic Emplacement								●									
Differential Geographic Positioning System					●				●								
Superconducting Quantum Interference Device									●								
Time Domain Electro-Magnetic Approach									●								
Remotely Controlled Unmanned Ground Vehicle										●	●			●			
Ballistic Disruption/Neutralization												●				●	●
X-ray Digital Imaging													●				
Polymer "muscle" actuators/manipulators														●			

Note 1: See Appendix I for name of system acronyms.
Note 2: This table is not all-inclusive. It is illustrative of the complexity and diversity of needs. It shows efforts directly related to Countermine and EOD. The other mission areas will leverage these systems, either directly or indirectly to meet their requirements.

3.5.5.1 Near and Mid Term Promising Technologies

For the near and mid terms, the best in detection class tool box should contain the following sensors processed with ATR to assist the human operator:

- Induction coil/Metal detector. Useful in ground and handheld detection.
- Multi-axis gradiometers. The ability to package five SQUID sensors in a hand held package will provide capability to detect, locate and classify.
- GPR. Detects surface and buried metal and plastic objects. Provides some classification capability. Useful in ground vehicle and handheld applications.
- Thermal imaging. Day/night surface detection with high resolution and size discrimination comparable to TV sensors. Sees metal and plastic items if temperature difference from background exists. Good for air, ground vehicle and hand held applications. Some capability against recently buried objects near surface and in arrays, i.e., new minefields. Fully develop polarization techniques for standoff detection and classification of surface targets.
- Advanced algorithms/ATR to lower probability of false alarm, Pfa, clutter reject and fusion of multiple sensors. Develop database of target signatures for use in development.

3.5.5.2 Longer Term Potential Technologies

The following sensors are expected to provide enhanced capability in 2005 and beyond.

- High Resolution Synthetic Aperture Radar (SAR) will provide high acuity, day/night, all weather imaging from the air for minefield detection and large UXO very near the surface.

- Biomimetic Systems will enable us to understand and duplicate multiple sensor capabilities of canine using olfaction, electro-optic imaging and other techniques.

- Hyperspectral Imaging will enable the use of air or ground platforms to detect the object and/or recently disturbed soil and foliage near UXO.

- Multi-Static Sensor Arrays will consist of acoustic, electromagnetic, magnetic sensors deployed in surface and bore hole array to provide data for inverse scattering processing over long time periods.

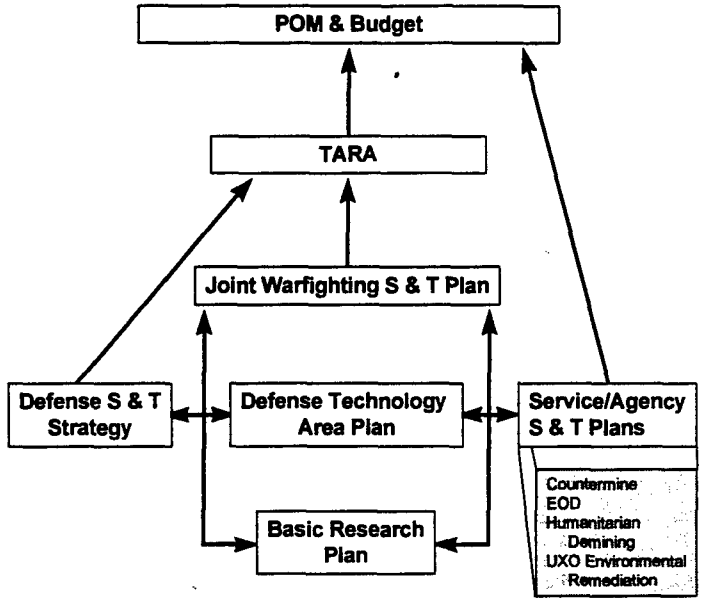
- Passive Millimeter Wave provides for imaging of buried targets by thermal imaging transmitted through ground.

3.5.6 Science and Technology Management

DoD's Science and Technology (S&T) program is focused, structured, and managed to ensure that superior technology, within the constraints imposed on us by our budgets, is achieved. The Defense S&T program is directed to meet the Warfighters' needs. The guidance, priorities, and principles set out in National Strategy are used to plan, to prioritize and to make choices within limited budgets. Both DoD corporate priorities and component priorities are observed. The result is a series of annual documents that implement this S&T Strategy. These documents are the Joint Warfighting S&T Plan, DoD Basic Research Plan, Defense Technology Plan, and various plans of the Military Departments and Defense Agencies. The current DoD Technology Area Review and Assessment (TARA) annually provides the review and assessment for oversight of Science and Technology (S&T) efforts. The formal review process includes four of the five UXO Mission Areas (Countermine, EOD, Humanitarian Demining and UXO Environmental Remediation). The other area, Active Range Clearance, leverages these advances, but relies primarily on Commercial Off The Shelf (COTS) products and services. Following the review, the TARA chair briefs the findings and recommendations to the Defense Science and Technology Advisor Group (DSTAG). Included in this briefing are program recommendations for termination, adjustment, and enhancement to better align the S&T program to comply with the guidance. Based on DSTAG recommendations and decisions, the issues are briefed to the Program Review Group (PRG), and program decision memorandums (PDMs) are issued as needed. This process is depicted in Figure 3-1.

The Joint Warfighting Science and Technology Plan (JWSTP), Defense Technology Area Plan and Basic Research Plan are the result of a strategic planning process that involves the Services, Joint Warfighter and Acquisition Communities. Service and agency programs are annually reviewed for compliance with these plans. The review is conducted by independent panels of experts led by senior technical staff members from the Office of the Director, Defense Research and Engineering. This strategic planning, review and assessment process is being applied to UXO clearance.

Figure 3.1. Technology Review and Assessment



3.5.7 Overview of S&T Programs

Basic research is investigating promising new technologies which include passive IR polarization, wideband IR, active laser ATR specifically focusing on small mines and UXOs, millimeter wave, chemically specific sensors, sensor fusion/signal processing, and x-ray detection innovations.

The Multidisciplinary University Research Initiative (MURI) includes fourteen universities teamed with eleven corporate partners to investigate a variety of detector modalities including IR, EO, acoustic and chemical. This effort will use orthogonal sensors coupled with automatic Target Recognition capabilities to facilitate clutter/noise reduction. DARPA has a three year initiative to investigate sensors for the detection of landmines via their chemical signatures - an electronic dog's nose. Additionally, DARPA is collecting background and clutter data for use in developing advanced algorithms and sensor fusion schemes. DARPA will be transitioning hyperspectral sensor technology for aerial detection.

The Army is conducting advanced sensor research to improve probability of detection for small non-metallic mines, decreasing false alarm rates, and improving standoff detection. This program is investigating new sensors, processing, and data fusion approaches. Additionally, the Army is exploring innovative concepts and technologies to support a lightweight airborne stand-off detection capability for limited area detection, reconnaissance and detection of nuisance mines along roads. A technology base effort will be initiated in FY98 to combine sensor and processing capabilities into an ATR program specifically oriented on UXO. This effort will be related to on-going ATR work for aerial and ground targets. Although many of the clutter and background issues are significantly different for UXO targets, the methodology and approach to the problems are similar.

The Army applied research efforts in development for UXO exploit features associated with radar, optical, thermal, sensor fusion and ATR. The Vehicular Mounted Mine Detector employs infrared and ground penetrating radar for detecting metallic and nonmetallic antitank mines. Sensor fusion and ATR

enhances detection speeds and reduces false alarm rates. A new technology base effort (Mine Hunter/Killer) will provide forward looking detection and neutralization of landmines. This system will incorporate a suite of sensors for standoff detection, integrated by sensor fusion and ATR to detect both antitank and anti-personnel mines. The Navy is funding two rapid prototyping efforts to improve the capability to detect buried UXO. The first is the Advanced Ferrous Ordnance Locator which provides a capability to map anomalies using acoustic or differential GPS navigation system. Location data is post processed to provide an anomaly map. The second EOD effort is a forward looking handheld GPR for detecting and classifying shallow buried targets and will provide a visual return to the operator for target identification. Additionally, technologies are being developed to address high threat UXO focus on time domain electro-magnetics (TDEM), SQUID gradiometers, signal processing, electronic monitoring, explosive detection, ATR and distributed robotics.

The Humanitarian Demining program objective in the clearance technology area is to adapt, when possible, COTS equipment while leveraging mature technology from Countermine, EOD, and other government organizations. The 1997 Humanitarian Demining program is also considering proposals that address requirements for large area clearance and neutralization. These technologies will be developed, demonstrated, and transitioned to the international demining community in ten to fourteen months. As part of the FY97 program, emphasis is being placed on transitioning items developed by the government to industry vendors. Several high potential items (mine rake, berm processing assembly, robotic mini-flails, multi-tined rollers and heavy grapnel) have been turned over to industry for design finalization and possible production.

UXO Environmental Remediation is primarily carried out through government contracts for UXO services (characterization, excavation, etc.). The technologies used to support remediation are currently commercial equipment available across the industry. In the future, technology development from Countermine, EOD, and Humanitarian Demining will form the bases for improved capability. Assessment of over sixty commercially available systems were conducted during Congressionally mandated Advanced Technology Demonstration (1994-1996). The latest round of demonstration results are not yet released. There appear, however, to be promising improvements in detection rates and reductions in false alarm rates.

3.5.8. Technical Review Summary

- New mine detection systems have transitioned from the Science and Technology base to PM management that provide a "first ever" capability to detect minefields and both metal and plastic mines, at standoff distances, from UAV, vehicle and man-portable platforms.
- DoD has increased Countermine-related research funding over the POM period.
- The MURI program in basic research for shallow buried UXO was initiated.
- The DARPA initiative in chemical sensing was initiated.
- DoD increased procurement funding for near term systems.
- DoD funded and directed the creation of a Center of Excellence for UXO Clearance.

3.6 Summary

The establishment of the Center of Excellence, with its coordination office, will serve to coordinate research and development efforts and promote standards and protocols, international cooperative efforts, and focus industry and other governmental agencies initiatives in this area. The Center will also provide an evaluation mechanism for new technologies applicable to UXO clearance. The new DoD UXO initiatives involving the Center of Excellence will ensure coordination of UXO efforts in the future to preclude duplication of effort.

Much effort was expended, to good effect, in the collection of information for preparation of this report. The technology subgroups found no critical duplication of efforts within DoD. The systems and technologies in development are complementary or mission specific. The ability to avoid future duplication of efforts will be one of the key coordination functions of the Center of Excellence.

Basic research efforts, such as those of MURI, DARPA and SERDP offer future technology solutions for difficult UXO technical problems to the entire community. Again, the Center of Excellence offers the ability to share this information widely and routinely across all the mission areas.

Technology base investments for more deeply buried UXO have been initiated in the SERDP and EOD applied research areas. These efforts must be closely tracked and coordinated for the earliest possible payoffs.

A technology base effort will be initiated in FY98 to combine sensor and processing capabilities into an automatic target recognition program specifically oriented on mines. This effort will piggyback on-going ATR work for aerial and ground targets. Although many of the clutter and background issues are significantly different for UXO targets, the methodology and approach to the problems are similar.

The leveraging of technology across all the mission areas is a daily event. Humanitarian Demining, for example, takes regular advantage of Countermine and EOD developmental programs. Some of the contingency systems sent to US forces in Bosnia began as Demining program systems. The Center of Excellence will formalize this interaction and institutionalize it.

The creation of a Defense Technology Objective (DTO) to address the specific needs of the Active Range Clearance and UXO Environmental Remediation communities would provide a more standard basis for their technology activities.

Periodic validation of requirements and priorities will continue on a bi-annual basis under the review and sponsorship of the Center of Excellence. This schedule will assist in the budget preparation cycle.

The keys to future success of DoD in this area are research and the Center of Excellence. The Center of Excellence provides an institutionalized focal point for coordination of needs, requirements, technologies and system solutions, research and resources. Through its Joint UXO Coordination Office, it will provide the continuity for coordination of these efforts. Oversight by senior DoD and Service representatives will ensure the efforts of the technology community to focus squarely and effectively on the needs of all the mission areas.

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Chapter 4

The Way Ahead

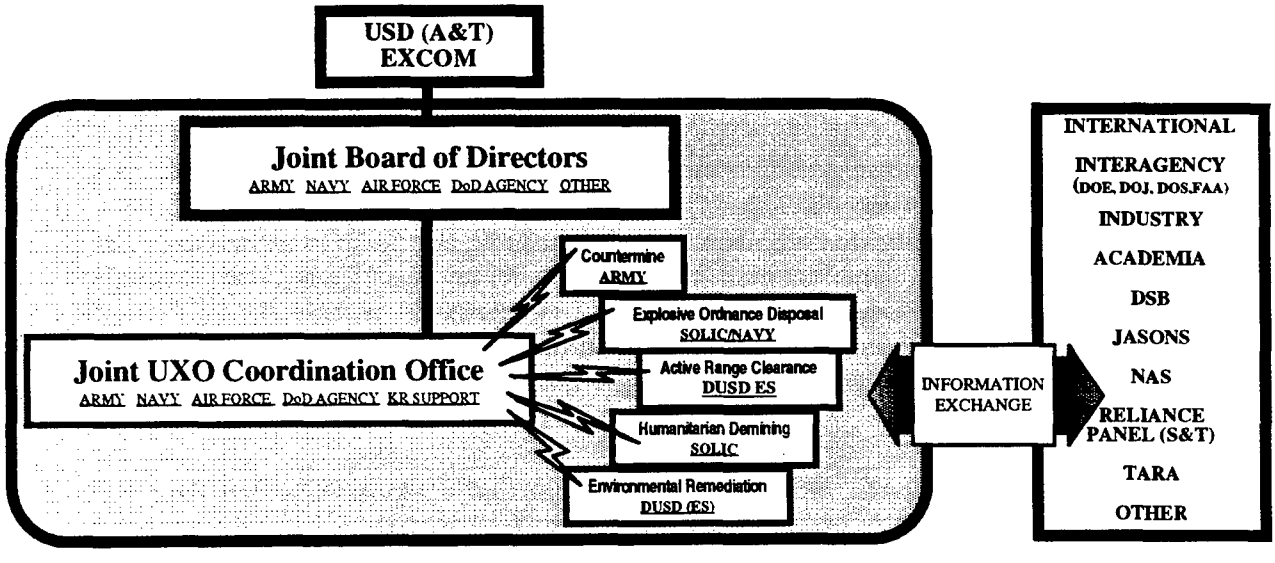
4.1 Introduction

The DoD has made significant progress in integrating the requirements and technology efforts of five diverse mission areas that support UXO clearance activities. The Executive Committee, the Clearance Steering Group and three subgroups conducted a requirements-driven review of technology. The review established a benchmark of current and emerging requirements as well as current and transitioning technologies to meet these requirements. This review was an essential step in harmonizing requirements and leveraging technologies to support all five mission areas. In order to maintain an enduring process for UXO technology development, the next step is for DoD to institutionalize this proven approach. This chapter describes the process and organizational relationships required to establish and maintain an effective, fully-coordinated, requirements-driven research and development program for UXO.

4.2 The Center of Excellence

In October 1996, the Under Secretary of Defense for Acquisition and Technology requested that the Clearance Steering Group examine a concept for a Center of Excellence to address the UXO technology issue. As a result, a unique approach for a Center of Excellence has been developed. In this context, the Center of Excellence is the *process* by which all five mission areas coordinate requirements and technology. In addition to the existing organizations that comprise the five mission areas, the Center of Excellence includes a Joint UXO Board of Directors and a Joint UXO Coordination Office (JUXOCO). The Center of Excellence will coordinate requirements and programs from the five mission areas, establish standards for testing, modeling, and evaluating UXO detection and clearance technology, and prepare an annual UXO research and development plan. The goal of the Center of Excellence is to help ensure there is no duplication of effort and to leverage the capabilities of other communities in other government agencies, in industry and academia, and in the international community. The concept for the Center of Excellence is depicted in Figure 4.1.

Figure 4.1 UXO Center of Excellence (The Way Ahead)



The Joint UXO Board of Directors will provide direction for the activities of the Center of Excellence. The Board will be comprised of flag-level Military Officers from the Services and Civilian equivalents from DoD proponent agencies for HD, ARC, and UER. Membership will come from both the requirements and technology communities. This composition will provide the necessary perspectives to develop balanced technology solutions. The members of the Joint UXO Board of Directors have responsibility for developing programs and budgets for their respective mission areas. Consequently, they are well positioned to resolve programmatic issues among the Services and DoD components. The Joint UXO Board of Directors will approve the annual UXO research and development plan and submit it to their respective DoD components for inclusion into the program and to OSD for review. The Board of Directors will have directive authority over the JUXOCO.

The JUXOCO will fulfill the day-to-day activities of the Center of Excellence in support of the Joint UXO Board of Directors. The JUXOCO will be jointly staffed by the DoD components that have an operational interest in UXO technology development. The JUXOCO will be established at Ft. Belvoir, Virginia and collocated with the Army Materiel Command's Night Vision/Electronics Sensors Directorate. This organization will be staffed by five to seven personnel with an appropriate level of contractor support, when required. In addition to providing the secretariat functions for the Board of Directors, the JUXOCO will be capable of providing DoD-wide coordination of UXO technology development to include proposing lead agencies for testing, modeling, and evaluating UXO detection and clearance technology.

The JUXOCO is the key element required to institutionalize the process adopted in the preparation of this report. The JUXOCO is an integrating and coordinating office which will work closely with the five mission areas, industry, academia, other US government agencies and international organizations. As an integral task, the JUXOCO will maintain the DoD UXO Technology Management Database. This comprehensive database, which was developed as a tool for the Clearance Steering Group to use in the preparation of this report, will be instrumental in maintaining a fully coordinated DoD development plan for UXO technology. The database will incorporate and disseminate technology information for all mission areas, technologies under development, investment levels, promising technologies, the technology centers performing the work, points of contact, contractual actions, test standards and protocols, and other information required to ensure the effective and comprehensive coordination across all mission areas. This database provides the Center of Excellence the capability to readily access and understand all UXO technology efforts that are underway in DoD. This database will also contain information on relevant technologies under consideration by industry, academia, and our allies. It will be a comprehensive data source for both government and non-government entities to understand our requirements, review ongoing technology investigations, and identify focal points to share results.

The technology centers supporting the five mission areas will serve as mission area experts in countermine, humanitarian demining, EOD, UXO environmental remediation, and active range clearance. The centers and sponsoring organizations will:(1) identify shortfalls in operational capability for UXO clearance; (2) identify which shortfalls require a materiel solution; (3) participate in the DoD Technology Area Review and Assessment (TARA) process; (4) coordinate with the JUXOCO and other technology centers for candidate technologies and programs to satisfy the requirements; and (5) prepare and submit to the Joint UXO Board of Directors an annual mission area research and development plan that addresses identified shortfalls.

The JUXOCO will conduct periodic reviews with inputs from the five mission area managers, other government agencies, and international partners. The reviews will ensure that: (1) requirements are

current and accurate; (2) opportunities for leveraging technologies are exercised; (3) duplicative programs are identified and eliminated; and (4) information on progress is shared. In addition, the JUXOCO and each mission area will jointly review funding adequacy and advise the Joint Board of Directors whether current UXO research and development efforts are in line with DoD priorities. The JUXOCO will produce an annual overarching UXO research and development plan for the Board of Directors using the respective mission area research and development plans and information obtained in the review process. The plan will include a roadmap that identifies near-term programs as well as plans for longer-term technical advances. The roadmap will include a funding overview, and an assessment of progress against established mission area goals.

The Center of Excellence will receive guidance and oversight from the DoD UXO Executive Committee (EXCOM) through the Board of Directors. The EXCOM provides senior level visibility of the UXO Center of Excellence and technology development efforts by the Office of the Secretary of Defense. The EXCOM will review the annual UXO Research and Development Plan, address issues raised by the Joint UXO Board of Directors, and evaluate the UXO technology development programs proposed by the mission area sponsors in program and budget submissions. As a minimum, the EXCOM will be composed of members representing OSD offices with oversight responsibilities for UXO programs to include the Director for Strategic and Tactical Systems, the Assistant Secretary of Defense for Special Operations and Low-Intensity Conflict, the Deputy Under Secretary for Environmental Security, and the Director, Research and Engineering.

The long-term management concept chosen for UXO technology development recognizes that the DoD has a compelling operational interest in ensuring critical warfighting capabilities remain the centerpiece of its technology development programs while supporting and enabling the development of technologies for Humanitarian Demining and Environmental Remediation at active and closing defense sites. This approach requires DoD to seek capability and capacity from the private sector for technology development. This private sector role is expected to become increasingly important in development and deployment of UXO clearance technologies. DoD is committed to establishing a more disciplined approach in defining technology requirements for Active Range Clearance and Environmental Remediation. It will enable the efficient transfer of technology developed for landmine detection, neutralization and disposal, Humanitarian Demining, and Explosive Ordnance Disposal to programs for Active Range Clearance and Environmental Remediation.

4.3 Summary

The DoD has significantly improved the coordination of technology requirements and programs to support UXO clearance. The S&T Reliance and TARA processes have helped focus our technologies programs. Initial steps have been taken to review UXO clearance requirements and survey programs and technologies currently available or transitioning in the near future to meet those requirements. While these initial steps have been beneficial, the DoD intends to institutionalize a process that efficiently applies available technology to satisfy the UXO clearance requirements.

The Joint UXO Board of Directors and the JUXOCO working in coordination with the technology centers and mission area sponsors defines the process that constitutes the DoD Center of Excellence for UXO. The Center of Excellence will be the hub for leveraging technology efforts to support UXO clearance. The Center of Excellence will have responsibility for coordinating technology requirements and capabilities from all five mission areas involved in UXO clearance. Private industry must play a role in innovation for technology for UXO detection and clearance. The DoD intends to expand

coordination with other government agencies and international activities through the UXO Center of Excellence. This management concept provides us the capability to link all organizations engaged in UXO technology horizontally and vertically. The availability of a comprehensive database will facilitate greater understanding across the department and with agencies outside the DoD. Finally, it will provide the opportunity for the Services and DoD components to act jointly or individually to optimize investment in UXO technology in those areas for which they have responsibility. It will provide the incentive to do so because the entire process will be more visible to the senior leadership in DoD and will provide the means for action by the senior leadership in DoD through the PBD process if the Services and other DoD proponents fail to act.

The Center of Excellence proposed in this study represents the evolution and institutionalization of the process implemented by the ad hoc Clearance Steering Group to produce this report. The Joint Board of Directors and the DoD Executive Committee represent a senior level Integrated Process Team (IPT) and an Overarching Integrated Process Team (OIPT) to oversee these efforts. This is fully consistent with the management reforms which are rapidly becoming the standard way of conducting business in the DoD and is the best way to ensure the interests of all relevant players are represented to maximize our investment utility in these important technology areas.

The structure for the UXO Center of Excellence will be effective October 1, 1997. In the interim the UXO Clearance Steering Group will continue as the IPT charged with the requirement to develop and coordinate the detailed mission, functions and statements of operating relationships for the Joint UXO Board of Directors and the JUXOCO.

Chapter Five

Summary and Conclusions

5.1 Summary

The Department of Defense has acted aggressively to respond to the direction of Congress and the recommendations of the General Accounting Office to improve the management of technology development for Unexploded Ordnance (UXO).

We have addressed all five critical missions in a comprehensive, holistic approach in the analysis of this problem. A key element in our approach was to identify and review the validated requirements in all five mission areas. As a result we now have a much better understanding of requirements for technology. This understanding of what we need and why we need it will enable us to focus and harmonize our research programs across DoD. This entire effort has been marked by an unprecedented level of harmony among the uniformed services. We have a common vision on how we should proceed.

A key to this effort and our continued successful management is the establishment of a unified database so that we can better know and more fully understand all of the work going on in these important mission areas. This database will enable the JUXOCO to serve with unparalleled effectiveness as a coordinating and integrating agent and clearinghouse for vital information on UXO technologies. It will provide, for the first time, a single point of entry into the system by interested parties outside DoD. It will be of inestimable value in coordinating and integrating our efforts inside the DoD. The collocation of this coordination office at Fort Belvoir with the U.S. Army Materiel Command at the Night Vision Electronic Sensors Directorate will provide several advantages: (1) it will keep the focus on technology development; (2) it will provide scientists and engineers for support who are already working on UXO technologies and who can provide assistance where necessary; (3) it will provide ready access, at no additional cost, to a fully developed staff of resource managers, lawyers and acquisition professionals to provide support and assistance; (4) it will provide the facilities, at no additional cost, to engage interested parties and provide information and assistance; and (5) it will provide the support facilities for the UXO Technology Management Database upon which our success in building a coordinated, unified technology development program is vitally dependent.

The JUXOCO will not supplant the important and useful work being done by other DoD elements such as the DoD S&T Reliance Process, the TARA process, the Defense Science Board, and other such activities. On the contrary, it will complement and facilitate those efforts by providing visibility across DoD on all UXO mission areas and by providing information and support.

The structure proposed in this study will provide the means for effective interagency support and operating relationships. In fact, as a result of this effort, a relationship has been formally established with the Department of Energy to capitalize on the impressive technical capabilities they bring to these programs. This interagency coordination will continue to expand as we continue to work with the Department of State on Humanitarian Demining Programs. We will expand our outreach to include the Department of Justice and the Federal Aviation Administration in areas where we have common interests with those agencies. We now have the means to facilitate an orderly, organized program with allies to share and receive technology information that we can use in our own technology development programs for UXO.

5.2 Conclusions

This study is the product of thousands of hours of effort by a joint service team. The intent, from the outset, was not to provide a highly technical report on the technologies and the technological process we are engaging to solve the problems associated with UXO in all five mission areas. The intent, instead, was to understand the process, to understand the requirements and to develop the means to improve our management of the resources and technology development in DoD and to do so in ways that recognized and remained sensitive to the critical warfighting capabilities which could be put at risk by a haphazard and uncoordinated approach to these issues.

The work done by the UXO Clearance Steering Group has laid the foundation and provided the structure to enable a fully integrated UXO technology management program in DoD. It will provide visibility across the services, a single point of entry for entities outside DoD to seek and provide information in these critical mission areas, and the means to integrate and coordinate programs across DoD. Importantly, through the Joint Board of Directors, both the opportunity and initiative is provided for concerted action across the Department. Opportunity to act derives from complete and timely information from the UXO Technology Management Database on what needs to be done to eliminate duplication, minimize investments and share technology. Incentive to act by the Joint Board of Directors derives from the certain knowledge that if the services acting jointly are unable or unwilling to address those issues, the Senior Leadership of the Department of Defense will do so. Countermine Operations and Explosive Ordnance Disposal and neutralization are critical warfighting capabilities. The indiscriminate seeding of landmines around the world by warring parties and the residual undetonated munitions hazards have created a humanitarian crisis that demands our attention. The clearance of our active ranges, closing bases, and Formerly Used Defense Sites (FUDS) are important national priorities. The common denominator for the solution of these complex problems is technology because technology that supports a soldier, sailor, airman or marine in detecting landmines in combat can also be used to detect unexploded ordnance on active ranges, at closing bases, and at FUDS sites as well as in the solution to the daunting Humanitarian Demining problem facing the civilized nations of the world.

We must use our resources wisely to effectively deal with these difficult and complex problems. As a result of this study, we know what must be done. We will act accordingly.

APPENDIX A

Requirements

Note: A total of 63 requirements appears in this appendix. Originally 166 requirements for UXO clearance were identified within the Department. After sorting the requirements into basic functional areas common to UXO clearance, the requirements subgroup reduced to 63 the number of requirements that meaningfully describe the needs of the five mission areas. The 63 remaining requirements listed in this appendix have the original assigned requirements numbers. As a consequence, there are gaps between numbers.

Number	Requirement Description
00001	Clear UXO including antipersonnel mines over extended areas in a non combat environment.
00002	Detector to search large areas and find UXO/UXO free areas mined/mine free zones in a non combat environment.
00004	Detect individual UXO including land mines with vehicle-mounted system in a non-combat environment
00005	Detect all types of buried UXO in all environments to a depth of 2 feet or less.
00006	Stand-off capability to detect electro-magnetic energy from standoff weapons that use internal sensors or command initiation.
00008	Identify all known chemical/biological agents in any physical state.
00009	Detect and determine x-y-z axis location of all types of ordnance buried to a depth of 20 feet.
00011	Airborne system for detection of UXO including antipersonnel and antitank metallic and non metallic mines on the surface or buried 2 feet or less.
00012	Tele-operated remotely controlled vehicle-mounted high-speed detection and marking of anti tank mines along a vehicle-wide path.
00013	Man carried system to detect all UXO including antipersonnel and antitank mines on the surface or buried down to a depth of 2 feet.
00014	Remotely perform beach and inland minefield/impact-area reconnaissance.
00015	Mark lanes breached through minefields during combat conditions.
00016	GPS linked physical/electronic system to mark mined/mine free areas during combat.

00019	High speed, explosive breaching of antitank and antipersonnel mines on land or in shallow water.
00020	Mounted high speed breaching through heavily defended minefield.
00021	Breach footpaths through antipersonnel land mines and light wire obstacles with a man-portable system from a position outside mine lethal distance.
00022	Man carried line charge to breach antipersonnel mines on the surface under combat conditions to facilitate self-extraction from mine field.
00023	Self extraction and protection plows and rollers for tank forces.
00024	Neutralize magnetically fuzed anti tank mines buried to any depth up to 2 feet.
00025	Clear mines and obstacles in a 50 meter wide lane through the surf zone and beach in order to land Landing Craft Air Cushion (LCAC) during amphibious assaults and inland expeditionary operations.
00026	Rapidly clear large beach areas for Landing Craft Air Cushion (LCAC) landing zone operations during amphibious assaults and inland expeditionary operations.
00027	Provide personnel protective ensemble to increase survivability from explosive blast and fragmentation.
00028	Provide kit to protect against mine detonation for wheeled vehicles.
00029	Remotely operated system to detonate or neutralize UXO/ mines.
00030	Surrogate mines and UXO for training.
00033	Conduct an in-stride explosive breach of antipersonnel and antitank mines under combat conditions.
00036	Prevent arming or firing of influence fuze while EOD procedures are performed.
00037	Defeat antidisturbance feature of all types of ordnance.
00038	Monitor status (armed/unarmed) of electromechanical fuzes during EOD operations.
00039	Provide personnel protection for performing EOD mission in toxic environment.
00041	Man-portable system capable of imaging ordnance buried to a depth of 10 feet with sufficient resolution to permit identification by type (i.e. bomb, rocket, projectile).
00043	Man-portable system that provides 3-D image of internal features of ordnance which is not buried.
00044	Examine stand-off weapons without actuating sensors
00045	Man-portable system to provide 3-D image of external features of ordnance on the surface or buried to 2 feet and positively identify ordnance by automated comparison/search of database.

00046	Image internal features of ordnance buried to 10 feet.
00047	Remotely determine status of electronic fuze.
00049	Determine explosive material composition.
00050	Neutralize to protect EOD personnel and contain contamination until final disposition.
00052	Rapidly acquire and evaluate intelligence information on UXO.
00055	Tool which can produce frequencies capable of switching electronic fuzes back into a safe condition.
00056	Remotely neutralize unseen, hidden, or embedded electronic fuze systems.
00057	Method required to gain access to internal area of UXO for the purpose of removing explosives or providing direct access to embedded fuzing systems.
00061	Permanent or temporary desensitizing of explosive material to allow for the separation of hazardous components.
00062	Rapidly neutralize large quantities of UXO over a large area by remote/stand-off means.
00063	Capture, separate, treat, and contain hazardous waste and toxic materials in a suitable condition while awaiting final disposition. Environmentally safe handling, movement, storage, and disposal procedures to eliminate the need for long term and costly handling.
00075	Detect all types of UXO at the surface or buried down to 6 inches.
00076	Detect and locate UXO which is buried to any depth down to 20 feet and possibly deeper.
00080	Ruggedized in-flight munition tracking system for use during development and testing of munitions.
00087	Improved robotics or remote control systems for gaining access to and recovering ordnance.
00089	Mechanized system for certification of range residue as inert.
00093	Remotely operated system to remove submunitions from roads and flat terrain.
00094	System to recover shrapnel and other non-hazardous residue.
00099	Perform rapid screening of large areas to determine presence or absence of UXO.
00103	Detect and accurately locate UXO at the surface or buried down to 10 feet or more in any terrain.
00110	Detect cases of glass vials or individual glass vials buried to any depth down to 2 feet.
00112	Automated digital Geographic Information System (GIS) to record location of detected ordnance.

00113	Automated digital Geographic Information System (GIS) to record the location of detected ordnance underwater to a depth of 300 feet.
00116	UXO identification by type.
00119	Underwater automated UXO excavation and recovery equipment.
00121	Lightweight blast and fragmentation barriers.
00161	Clear the surf zone (SZ) and beach zone (BZ) of mines and obstacles in order to land LCAC during amphibious assaults and expeditionary operations.
00163	Automated database system to collect, store, analyze and disseminate information on areas containing UXO/minefields.
00166	Neutralize/vendor safe vehicle improvised explosive devices.

APPENDIX B

DOE Interlaboratory Task Force Participants

Argonne National Laboratory

Brookhaven National Laboratory

Idaho National Engineering Laboratory

Lawrence Berkley National Laboratory

Lawrence Livermore National Laboratory

Los Alamos National Laboratory

Oak Ridge National Laboratory

Pacific Northwest Laboratory

Sandia National Laboratory

Savannah River Technology Center

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APPENDIX C

Data and Information Exchange Agreements

1. Countermine

a. United Kingdom, IEA-UK-A-A-95-1506, Countermine Technologies

Scope: This exchange is intended for the US and UK to share information on research, test, and evaluation of mutual interest on Countermine technologies:

1) Mechanical, chemical and explosive mine neutralization technology, and mine blast survivability.
2) Standoff, vehicle mounted and hand-held mine detection technology.
3) Mine and minefield marking technology.
4) Program plans, milestones, schedules, funding levels and development status.
5) Performance data.
6) Organizational structures and engineering capabilities of the applicable governmental and industrial engineering centers and testing facilities.
7) Performance specifications, user requirements, modeling, operational and mission area analyses, design concept, studies and system performance analyses.

b. Japan, DEA-A-83-JA-1290, Countermine Research, Development, Study and Systems

Scope: This Annex provides for the exchange of information concerning technical data related to research, development, test, and evaluation of systems and technologies in:

1) Mine/minefield detection, to include detection of individual mines and minefields using close-in and stand-off equipment and technology, and
2) Mine/minefield neutralization, to include avoidance, deception, destruction, and damaging mines; vehicle protection and hardening; and applications of robotics and automated equipment and technology.

c. Germany, DEA-A-58-GE-0005, Detector for Non-Metallic Mines

Scope: This Annex provides for the exchange of information concerning mines and mine detection.

d. Germany, DEA-A79-GE-1248, Countermine Warfare Materiel

Scope: This Annex provides for the exchange of information concerning research, development, test and evaluation data on mine clearing and new mine clearing techniques and on equipment and technology for degaussing tanks and other combat vehicles for purpose of suppressing the magnetic signatures.

e. Korea, DEA-A-81-KS-1283, Countermine Measures

Scope: This Annex provides for the exchange of research, development, test and evaluation information on Countermine systems (including mobility equipment technology), Countermine and counter-barrier techniques, and mine neutralization/detection.

f. France, DEA-A-77-FR-1235, Counterbarrier Warfare

Scope: This DEA provides for the exchange of data on the following combat engineering equipment: mine detectors and detection techniques, mine neutralization systems and other countermeasures to barriers to include defeat of barbed wire, barbed tape, and antitank obstacles.

g. Sweden, DEA-A-79-SW-1232, Counterbarrier Warfare

Scope: This Annex provides for the exchange of information concerning combat engineering equipment: mine detectors and detection techniques; mine neutralization systems; countermeasure to barriers to include defeat of barbed wire, barbed tape, and antitank obstacles.

2. Explosive Ordnance Disposal

a. Mutual Weapons Development Data Exchange Agreements (MWDDEAs) and EOD Annexes

Country	Original Annex Number	Date Signed	Navy Only Annex	Date Signed
Belgium	A/N-67-B-1076	12 JUN 67	N-XX-B-4608	Unsigned
Denmark	A/N-67-D-1077	08 MAY 67	N-95-D-5006	NOV 95
Egypt	N/A	N/A	N-96-EG-6200	AUG 96
France	A/N-93-F-5651	15 AUG 84	N-93-F-5651	FEB 94
Germany	A/N-67-G-1078	23 MAY 67	N-96-G-4203	APR 96
Israel	A/N-70-IS-4105	22 DEC 70	N-94-IS-4109	AUG 95
Netherlands	A/N-67-TN-1081	08 MAY 67	N-93-TN-4829	DEC 93
Norway	A/N-67-N-1080	18 AUG 67	N-XX-N-5216	Unsigned
Sweden	N/A	N/A	N-94-S-5422	JUN 94

Scope: These agreements cover the exchange of research and development information in the field of Explosive Ordnance Disposal (EOD). They include information on the development of equipment and techniques for disposal of air, surface, and underwater explosive ordnance. Information within the following areas is exchanged under these DEAs:

(1) The development of equipment for neutralizing or destroying terrorist devices and for recovering, investigating, and rendering them safe, with special emphasis on remote control initiation devices.

(2) The development of equipment for locating, identifying, rendering safe, recovering and

disposing of air-dropped area denial munitions, including technical information on selected items of air dropped area denial munitions and air-delivered chemical ammunition.

(3) The development of equipment for locating, identifying, rendering safe, recovering and disposing of surface ordnance, including technical information on selected items of surface ordnance and surface-delivered chemical ammunition.

(4) The development of equipment for locating, identifying, rendering safe, recovering and disposing of underwater mines, including limpet mines.

b. America, Britain, Canada, and Australia (ABCA) Multilateral Information Exchange Project (IEP)

Countries:	America, Britain, Canada, Australia
Annex Number:	ABCA-5 (-5 indicates the subject is EOD)
Date Signed:	01 OCT 70

Scope: Areas of exchange covered by this IEP annex are the same as covered under the bilateral MWDDEA EOD Annexes.

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APPENDIX D

Funding

The DoD is investing $129.4 million in fiscal year 1997 and $174.6 million in the fiscal ear 1998 for technology development to support UXO clearance. A summary of the funding is shown in Table D.1. A more detailed funding table is at Table D.2. The funding layout also contains out-year RDTE and procurement funding associated with fiscal year 1997 and fiscal year 1998 development efforts.

Table D.1 UXO Clearance Funding Summary ($K)

Mission Area	Program Element	FY97	FY98
Countermine	0601103D	3100	3100
	0602313M	1200	1000
	0602712A	5510	8711
	0602702E	6800	12000
	0603606A	6215	10597
	0603619A	27180	15115
	0603619M	2800	-0-
	0603640M	-0-	2200
	0604612M	3500	2200
	0604649A	34100	43700
	0604808A	2172	22605
	0604808M	-0-	3100
	E72800(Ammo)	4300	4800
	M80100(OPA)	-0-	12600
	0603782N	800	-0-
EOD	0602315D	250	250
	0602315N	2815	2250
	0603112D	50	-0-
	0603122A	495	600
	0603122D	734	75
	0603654D	600	1085
	0603654N	2633	2645
	0603709D	400	600

Humanitarian Demining	0603120D 0603920D	14369 -0-	7663 10000
Active Range Clearance	0603709D	900	1000
Environmental UXO Remediation	0601102A 0602720A 0603709D 0603716D 0603851D	6 4006 1800 2400 300	205 337 1000 2900 750
Center of Excellence	0602712A	-0-	1500
Total		129435	174588

Table D.2 UXO Clearance Funding Details ($K)

MISSION	PROJECT/TASK	PE	FY97	FY98
Countermine	ASTAMIDS	0602712A		750
		0603606A		
		060319A	11516	
		060408A	522	13873
	COBRA	0602313M	1200	1000
		0603640M		2200
		0604612M	3500	2200
	HSTAMIDS	0603619A	9342	7983
		0604808A		
	VMMD ATD	0603606A	6215	3000
	IVMMD	0604808	1650	
		M80100 (OPA)		12600
	VMMD	0603619A		7132
	(GSTAMIDS)	0604808A		
	MHK	0602712A	4010	5461
	MHK ATD	0603606A		7597
	Hunter Enhancement	0603606A		
	Advanced Mine Detection Sensors	0602712A	1500	1750
	LAMS	0602712A		750
	DARPA	0602702E	6800	12000
	MURI	0601103D	3100	3100
	ESMB	0603619A	6322	
		0603619M	2800	
		0604808A		8732
		0604808M		3100
	GRIZZLY	0604649A	34100	43700
	JAMC	RDTE	800	

MISSION	PROJECT/TASK	PE	FY97	FY98
	APOBS	E72800(AMMO)	4300	4800
EOD	AOL	0603654N	25	
	AFOL	0603122D	49	
	FLHR	0603122D	200	
	SQUID	0602315N		400
	TDEM	0602315N		200
	Advanced Bomb Suit	0603122A	495	600
		0604713A		
	RECORM	06043654N	100	
	ARS	0603654N	1086	400
	Case Entry	0603122D	275	75
	IED Visualize	0603122D	210	
	ESAF Monitor	0602315N	500	350
	Auto-RECORM	0603709D	400	
	Sensor Defeat	0602315D	250	250
	MCD	603654D	600	1085
	RONS	0603654N	838	1485
	LIDDS	0603654N	584	760
	Standoff Disrupt	0603112D	50	
	HLONS	0602315N	800	500
	BUGS	0602315N	1215	500
		0603709D	0	600
		0603654N		
	Robotic Systems	0602315N	300	300
Humanitarian Demining		0603120D	14369	7663

MISSION	PROJECT/TASK	PE	FY97	FY98
		0603920D	0	10000
Active Range Clearance	SMCV	0603709D	900	1000
UXO Environmental Remediation	SOCS	0603709D	800	500
	JPG	0602720A	4000	
	REVS	0603709D	600	300
	AOE	0603709D	400	200
	SERDP	0603716D	2400	2900
	ESTCP	0603851D	300	750
	EQ	0601102A	6	205
		0602720A	6	337
Center of Excellence		0602712A		1500
		TOTAL	129435	174588

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APPENDIX E

Examples of UXO Detection

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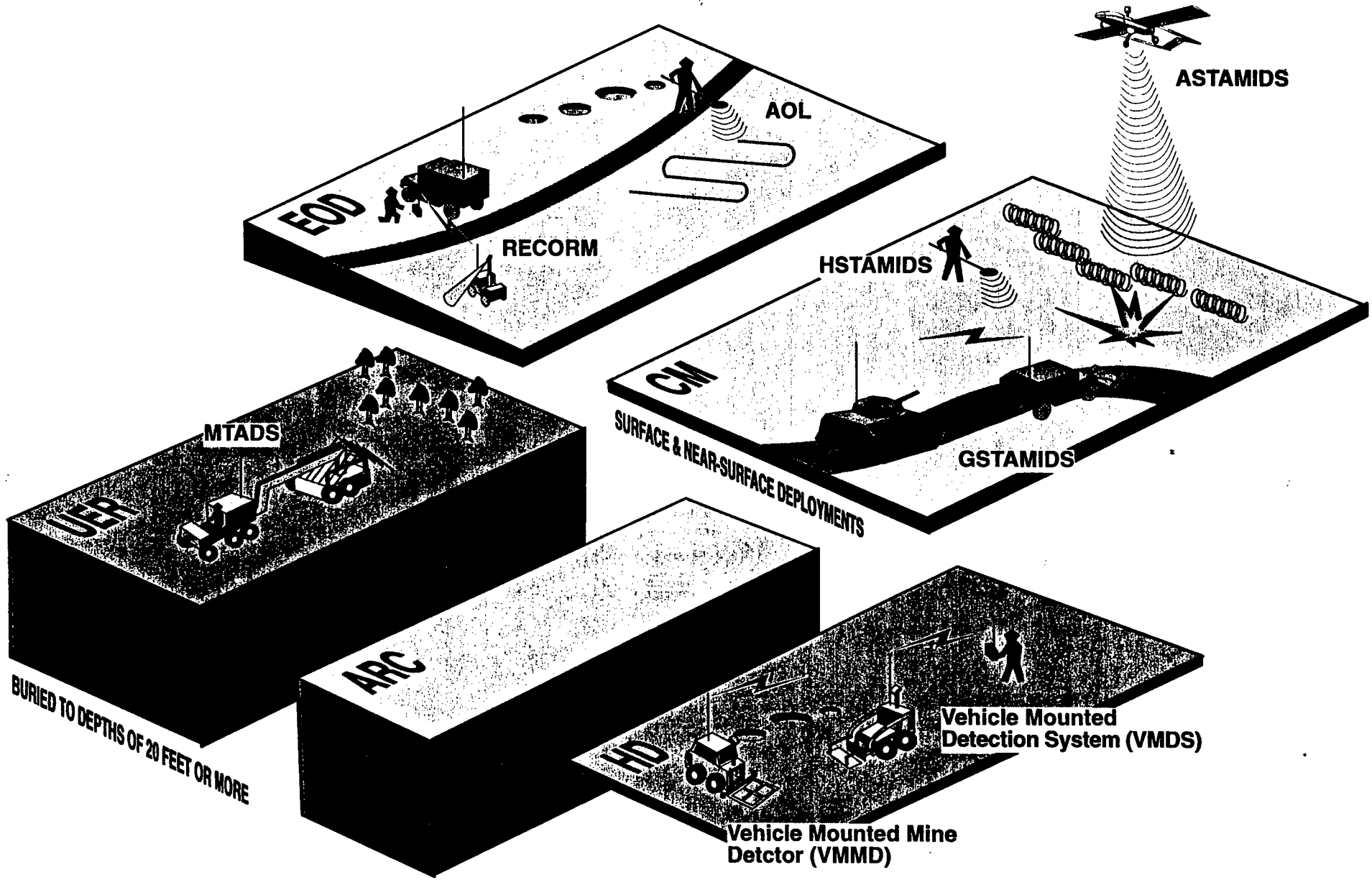
EXAMPLES OF UXO DETECTION



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APPENDIX F

Examples of UXO Disposal

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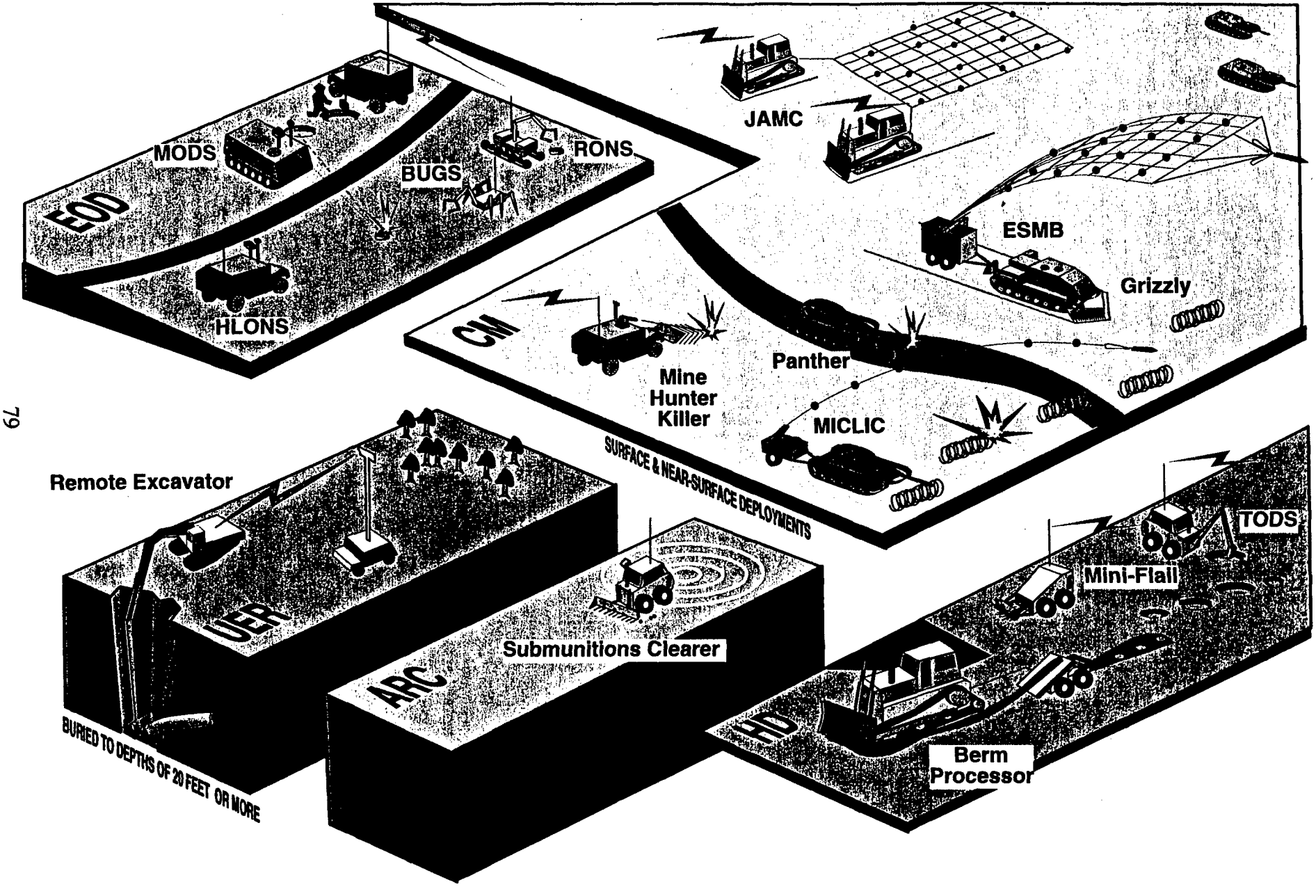
EXAMPLES OF UXO DISPOSAL



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APPENDIX G

Analysis of Development Efforts to Support Requirements

The two technology sub-groups held extensive meetings to discuss and compare the efforts currently underway to support the requirements of each mission area. The scope of the technology analysis effort basically involved examining programs funded by the five mission areas. The subgroup meetings allowed technologists from each area to understand both the need for the on-going effort and the reasoning behind the technical approach taken for each effort. Understanding these two points allowed the technologists to compare and contrast each of the efforts in the context of the needs of their mission areas. Each of the 63 requirements were reviewed and the efforts that could support these needs were identified. Areas for leveraging were identified in the detection and neutralization functional areas. The recovery and disposal functional area were also identified as areas where little effort has been applied. This review allowed the technologists and resources managers to better understand how they can leverage the efforts in other mission areas and also to identify mission unique requirements that they need to focus on.

There are, of course, a variety of technology and program areas which touch in some way on detection and neutralization. Leveraging and coordinating these technologies will be advanced through the OSD Basic Research Plan, the Defense Technology Area Plan, and the OSD Technology Area Review and Assessment (TARA) Process.

The following figures provide a listing of the needs identified by the five communities. They are broken out functionally because the utility of the technology efforts to solve these requirements span multiple mission areas. In each of the charts, the developmental systems are listed for the mission areas. Upon review, a number of efforts are underway to research, develop and demonstrate concepts for the detection of and disposal of UXO.

Detection

When reviewing actual investment in technology development currently being made in the detection, we discovered the preponderance of the investment has been in the detection of shallow buried land mines. The detection technology development efforts currently underway in the technology base are primarily concept specific. DARPA is conducting a series of clutter experiments to better understand the background signatures. The Army Corps of Engineers is supporting these experiments and will be focusing additional technology-base efforts in order to better understand the dynamics of site conditions on the different sensors and, in particular, the generations of false alarms. This work will involve the quantification of site characteristics in terms of sensor packages and correlation of site conditions with the generation of false alarms. This should provide insight into data fusion strategies that might be effective in reducing false alarm rates. The Multi-University Research Initiative (MURI) investment will be focused on basic signature, clutter and associated problems plaguing the entire UXO community. The DARPA and MURI investments should provide a solid basis for future investment.

DARPA is investigating, in a multi-year program, detection of land mines and shallow buried UXOs by exploitation of their chemical signatures. This program is motivated by the ability of canines to

detect mines. The results are expected to have application in all areas of explosives and mine detection research. The Countermine and Humanitarian Demining mission areas are actively following and supporting this research effort. In addition, DARPA is completing a 6.2 effort in the area of hyperspectral detection of land mines from an airborne platform. This research effort is expected to contribute to the Light Weight Airborne Multispectral Detection System (LAMS) program, discussed below.

In the airborne detection area, the Countermine investment in ASTAMIDS could be leveraged by the other communities. ASTAMIDS program uses active/passive IR. At the JPG an airborne ground penetrating radar was demonstrated. It did not perform to the claims of the GPR developers. The demonstration of ASTAMIDS and the DARPA hyperspectral imaging system should include a representative UXO test set. The DARPA hyperspectral program has shown promise and will be incorporated into the FY98 Army Science and Technology Objective program called Light Weight Airborne Multispectral Detection System (LAMS) which may result in product improvement for the ASTAMIDS. LAMS will also incorporate new staring focal plane array, passive polarization implementation in focal plane array and hyperspectral technology resulting in enhanced mine detection.

The investments currently being made in ground vehicle platform based sensor configurations do not overlap. The GSTAMIDS utilizes GPR, IR and inductance sensors in front of the vehicle to alert the operator to a potential shallow buried threat from a standoff distance on a flat even route. The basic research program in forward looking radar is showing the potential to provide standoff detection from a safe distance at increased speed. The demonstration of MTADS has shown the utility of ganged array systems towed behind a vehicle for sweeping large open areas containing buried UXO. The Auto-RECORM effort provides a small remote vehicle for surface UXO detection and identification. All of these platforms can benefit from enhanced sensors and automated target recognition.

The R&D investments in hand-held detection equipment are directed at an attempt to improve the performance of existing equipment. The HSTAMIDS will detect shallow buried mines through the use of multi-sensor fusion. The AOL will provide the EOD technician with the capability to rapidly survey an area for buried UXO and provide a means to post process the data. The MURI and DARPA efforts can help enhance these programs.

Little effort has been directed toward developing an ATR system to distinguish mines from clutter. Current technology efforts have been directed at developing sensors to detect both metallic and nonmetallic mines/UXOs.

Table G.1 Detection

Requirement Definition/Description	Developmental System
Detector to search large areas and find UXO/UXO free areas in a non-combat environment. (UXO ID# 2)	MURI, IR SYSTEM, SERDP SAR
Detect individual UXO including land mines with vehicle-mounted system in a non-combat environment. (UXO ID# 4)	IVMMD, GSTAMIDS
Detect all types of buried UXO in all environments to a depth of 2 feet or less. (UXO ID# 5)	HSTAMIDS, AOL, FLHR, DARPA, TDEM
Standoff capability to detect electro-magnetic energy from standoff weapons that use internal sensors or command initiation. (UXO ID# 6)	ESAF DETECTOR

Detect and determine x-y-z axis location of all types of ordnance buried to a depth of 20 feet. (UXO ID# 9)	MTADS, SOCS, JPG DEMO
Airborne system for detection of UXO including antipersonnel and antitank metallic and non-metallic mines on the surface or buried 2 feet or less. (UXO ID# 11)	ASTAMIDS, COBRA, LAMS, SERDP SAR
Tele-operated, remotely controlled, vehicle-mounted, high-speed detection and marking of antitank mines along a vehicle-wide path. (UXO ID# 12)	IVMMD, GSTAMIDS, MTADS
Man-carried system to detect all antitank and antipersonnel mines as the surface or buried down to a depth of 2 feet. (UXO ID# 13)	HSTAMIDS
Remotely perform beach and inland minefield reconnaissance. (UXO ID# 14)	COBRA
Detect all types of UXO at the surface or buried down to 6 inches. (UXO ID# 75)	HUNTER-KILLER, TNA, MURI, SERDP, TDEM
Detect and locate UXO buried to any depth down to 20 feet and possibly deeper. (UXO ID# 76)	MTADS, SOCSM AFOL, AOL, SQUID, TDEM
Perform rapid screening of large areas to determine presence or absence of UXO. (UXO ID# 99)	AutoRECORM
Detect and accurately locate UXO at the surface or buried down to 10 feet or more in any terrain. (UXO ID# 103)	GSTAMIDS, MTADS, SOCS
Detect cases of glass vials or individual glass vials buried to any depth down to 2 feet. (UXO ID# 110)	Footnote 7

Location

Efforts in the mapping area are all based on commercially available navigation sensors and software mated to platforms. The marking efforts are primarily in support of Countermine to ensure breached lanes or mined areas are clearly marked. Some of the requirements do not currently have a capability or a development program to provide a capability. The mapping and marking areas have received less interest than other areas.

Table G.2 Location

Requirement Definition/Description	Developmental System
Mark lanes breached through fields containing UXO, including mines, during combat conditions. (UXO ID# 15)	Grizzly
GPS-linked physical/electronic system to mark UXO/UXO-free areas. (UXO ID# 16)	GSTAMIDS
Automatic digital Geographic Information System (GIS) to record location of detected ordnance. (UXO ID# 112)	AFOL, AOL, MTADS, JPG DEMO

7 Potential solutions will be pursued through the OSD technology Assessment Review.

Automated digital Geographic Information System (GIS) to record the location of detected ordnance underwater to a depth of 300 feet. (UXO ID# 113)	
Automated database system to collect, store, analyze, and disseminate minefield information on areas containing UXO/minefields. (UXO ID# 163)	Footnote 8

Breaching

Breaching is a method to clear openings through minefields. This thrust includes distributed explosives and armored vehicles with plows/rakes/flails/rollers. Grizzly will provide a mounted complex obstacle breaching capability for the combat force. ESMB will provide a standoff capability which may be used in conjunction with the Grizzly to mitigate risk to the Grizzly by eliminating minefields that are part of the obstacle system. APOBS will provide a similar capability for obstacles to dismounted soldiers. BCIS will provide an in-stride, track width only capability for the M1 tank equipped portion of our forces. These systems are all complementary in reducing obstacles to maneuver on the battlefield.

Table G.3 Breaching

Requirement Definition/Description	Developmental Systems
High-speed, explosive breaching of antitank and antipersonnel mines on land or in shallow water. (UXO ID# 19)	Grizzly, ESMB
Mounted high speed breaching through heavily defended minefield. (UXO ID# 20)	Grizzly, ESMB
Breach footpaths through antipersonnel land mines and light wire obstacles with a man-portable system from a position outside mine lethal distance. (UXO ID# 21)	APOBS
Man-carried line charge to breach antipersonnel mines on the surface under combat conditions to facilitate self-extraction from mine field. (UXO ID# 22)	APOBS
Self-extraction and protection plows and rollers for tank forces. (UXO ID# 23)	BCIS
Clear mines and obstacles in a 50-meterwide lane through the surf zone and beach in order to land Landing Craft Air Cushion (LCAC) landing zone operations during amphibious assaults and inland expeditionary operations. (UXO ID# 25)	
Rapidly clear large beach areas for LCAC landing zone operations during amphibious assaults and inland expeditionary operations. (UXO ID# 26)	
Remotely operated system to detonate or neutralize mines. (UXO ID# 29)	BUGS
Conduct an in-stride explosive breach of antipersonnel and antitank mines under combat conditions. (UXO ID# 33)	Grizzly, ESMB~~S~~
Clear the surf zone (SZ) and beach zone (BZ) of mines and obstacles in order to land LCAC during amphibious assaults and expeditionary operations. (UXO ID# 161)	

8 Minefield Database Recording System developed using FY96 funds offers partial solution.

Access

The access area applies to all mission areas. It is a primary consideration of the EOD mission area, since the EOD technician must come in close proximity to the UXO to perform a render safe mission. A number of efforts exists to provide personal protection and remote means of accessing an area containing fuzed UXO.

Table G.4 Access

Requirement Definition/Description	Developmental System
Provide personnel protection ensemble to increase survivability from explosive blast and fragmentation. (UXO ID# 27)	Advanced Bomb Suit, BASIC
Provide kit to protect against detonation damage to wheeled vehicles. (UXO ID# 28)	
Defeat antidisturbance feature of all types of ordnance. (UXO ID# 37)	SENSOR DEFEAT
Provide personnel protection for performing EOD mission in toxic environment. (UXO ID# 39)	RECORM
Method required to gain access to internal area of UXO for the purpose of removing explosives or providing direct access to embedded fuzing systems. (UXO ID# 57)	CASE ENTRY, Sensor Defeat, ESAF Monitor

Identification and Evaluation

The identification area is one that will become of increasing interest as the detection technology questions are answered. The ability to identify type, fuzing mechanisms and fillers of UXO has already become an important issue in clearances such as the clearance of suspected chemical shells in the Spring Valley area of Washington, D. C.. This area is also primarily an EOD mission area and all of but one of the efforts in this area are funded by the EOD program elements. The DARPA explosive detection program may provide additional capability in this area to determine precisely the contents of UXO.

Table G.5 Identification and Evaluation

Requirement Definition/Description	Developmental System
Identify all known chemical/biological agents in any physical state. (UXO ID# 8)	DARPA
Monitor status (armed/unarmed) of electromechanical fuzes during EOD operations. (UXO ID# 38)	ESAF Monitor
Man-portable system capable of imaging ordnance burned to a depth of 10 feet with sufficient resolution to permit identification by type (i.e., bomb, rocket, projectile). (UXO ID# 41)	
Man-portable system that provides 3-D image of internal features of ordnance that is not burned. (UXO ID# 43)	IED Visualization, ARS
Examine standoff weapons without actuating sensors. (UXO ID# 44)	ESAF Monitor

Man-portable system to provide 3-D image of external features of ordnance on the surface or buried to 2 feet and positively identify ordnance by automated comparison/search of database. (UXO ID# 45)	
Image internal features of ordnance buried to 10 feet. (UXO ID# 46)	
Remotely determine status of electronic fuze. (UXO ID# 47)	ESAF Monitor
Determine explosive material composition. (UXO ID# 49)	DARPA
Rapidly acquire and evaluate intelligence information on UXO. (UXO ID# 52)	
UXO identification by type. (UXO ID# 116)	AutoRECORM

Neutralization

The ability to neutralize UXO once it has been detected, accessed and identified means different things to different UXO mission areas. For Countermine and Humanitarian Demining, neutralizing means eliminating the UXO hazard in place while trying to limit collateral damage. Explosive and low order detonation techniques are acceptable. For the other communities these techniques are used but may not be acceptable in all cases. On site render safe procedures to limit collateral damage or to allow the movement of an UXO item to a disposal site are also needed. Demining, Active Range Clearance and UXO Environmental Remediation are also interested in clearing large areas as quickly and as inexpensively as possible.

The technologies in this area can be broken down into three categories: standoff disruption, remote equipment and hand tools. Hand tools are developed and used by the EOD community to perform render safe procedures and are made available to military and private contractors EOD operators for their use in support of active range and UXO Environmental Remediation actions. The use of some form of directed energy to cause a reliable low order reaction to perform standoff disruption is the focus of both a Countermine and EOD effort. The Countermine effort uses a kinetic energy slug (a 25mm cannon round) to attempt to cause a low order detonation of buried mines from a 30 meter standoff distance. The EOD effort focuses on using a high power laser to cause burning or low order detonation of surface UXO from distances of 50 to 200 meters. The kinetic energy slug has a ground penetrating capability, but a shorter standoff distance. The laser can not penetrate the ground but provides a safer standoff distance when operating against UXO that contains shaped charges that may propel a jet for more than 30 meters.

The last category in this functional area is remote equipment. This area has the largest area for potential overlap and was reviewed in detail. Each of the communities has made an investment in this area over the last 10 years because of the obvious hazard reduction possibilities. Many of the efforts in this area are coordinated through the Joint Robotics Program (JRP). The Active Range Clearance efforts and many of the EOD efforts are directly funded by the JRP and are coordinated through the Unmanned Ground Vehicle Master Plan. The remaining efforts were reviewed by the sub-group and found to have significant mission oriented differences. The sub-group has also established working relationships between the remote vehicle developers in each community to ensure existing efforts are well leveraged and no duplication exists in the future.

Table G.6 Neutralization

Requirement Definition/Description	Developmental System
Clear UXO including antipersonnel mines over extended areas in a non-combat environment. (UXO ID# 1)	MINE RAKE, BPA, TODS
Neutralize magnetically fuzed UXO, including antitank mines, buried to any depth up to 2 feet. (UXO ID# 24)	MHK
Prevent arming or firing of influence fuze while EOD procedures are performed. (UXO ID# 36)	SENSOR DEFEAT
Neutralize to protect EOD personnel and contain contamination until final disposition. (UXO ID# 50)	
Tool that can produce frequencies capable of switching electronic fuzes back into a safe condition. (UXO ID# 55)	
Remotely neutralize unseen, hidden, or embedded electronic fuze systems. (UXO ID# 56)	STANDOFF DISRUPT, MCD HLONS, MHK, RONS, ROBOTIC SYSETMS
Permanent or temporary desensitizing of explosive material to allow for the separation of hazardous components. (UXO ID# 61)	
Rapidly neutralize large quantities of UXO over a large area by remote/stand-off means. (UXO ID# 62)	HLONS, MHK, SMCV, BUGS, LIDDS
Neutralize/render safe vehicle improvised explosive devices. (UXO ID# 166)	

Recovery

Currently multiple false targets are excavated for each actual UXO item detected. Even as the false alarm rate is reduced with investments in the detection area, the preponderance of UXO clearance time for the UXO Environmental Remediation community is and will be spent on excavating buried UXO. The Joint Robotics Program is currently making the investment in this area to support UXO Environmental Remediation.

Table G.7 Recovery

Requirement Definition/Description	Developmental System
System to recover shrapnel and other nonhazardous residue. (UXO ID# 94)	

Disposal

This area is not currently receiving any investment from the DoD for UXO. One outstanding need is the mechanized certification of range residue - a high priority requirement for the active range

community. One active range is working with a private contractor, at no cost to DoD, to demonstrate the application of a rock crushing device to partially solve this problem. The most technically challenging areas is the environmentally compliant field disposal of explosive material. There does not currently exist a field portable method for disposing of small numbers of highly dangerous land mines and small UXO in an environmentally compliant manner. Current demilitarization technologies such as plasma arc furnaces, molten salt baths, silver ion processing, etc. are too large in size for field use.

Table G.8 Disposal

Requirement Definition/Description	Developmental System
Capture, separate, treat, and contain hazardous waste and toxic materials in a suitable condition while awaiting final disposition. Environmentally safe handling, movement, storage, and disposal procedures to eliminate the need for long term and costly handling. (UXO ID# 63)	
Mechanized system for certification of range residue as inert. (UXO ID# 89)	
Remotely operated system to remove submunitions from roads and flat terrain. (UXO ID# 93)	SMCV
Lightweight blast and fragmentation barriers. (UXO ID# 121)	

Training

Technology training aids are currently provided on an ad-hoc basis as operation occur. A centralized effort to provide training aids to all the communities needs to be established.

Table G.9 Training

Requirement Definition/Description	Developmental System
Surrogate mines and UXO for training. (UXO ID# 30)	

APPENDIX H

UXO Technology Management Database

Since its inception in September 1996, the UXO Technology Management Database has evolved with the UXO clearance program to its current state. The database, created in Microsoft Access 2.0, contains information on all of the UXO clearance requirements from the five mission areas, as well as information on the projects and technologies being researched, developed, or acquisitioned for UXO clearance, and information about all points of contact for the requirements and projects. Information about each requirement includes: an identification number, a short description, operational parameters, primary and associated functional areas, and a priority rating of (H=high, M=medium, L=low, or N=no interest) from each of the mission areas. Each project record has an identification number, a project title, a description, a program element number, and funding information (currently FY97-FY03). Each technology has an identification number, a name, and a description. The point of contact information includes name, address, telephone number, fax number, and email address.

Through the creation of relationships in the database, each requirement is linked to all projects working in part or wholly toward fulfilling that requirement. In turn, each project is linked to technologies which are being used, researched, developed, or acquisitioned as part of that project. Each requirement and each project is linked to point of contact information. The relationships can be visualized in reports generated by the database. For example, one could print all of the requirements in the functional area of Identification with the associated detection and disposal projects listed under each requirement. Or, one could print a list of all detection technologies and descriptions of those technologies.

Figures H.1, H.2, and H.3 show some of the menus which guide the user to the desired form or report in the database. For example, Figure H-1 contains the main menu of the Database. Clicking on the "Reports" button moves the user to the screen in Figure H-2. Then by clicking the button, "Reports of Requirements and Supporting Projects Grouped by Mission Area" the user opens the menu in Figure H-3. From this screen, the user can choose to view one of the listed reports.

The searching and sorting capabilities of the database were extremely useful during the requirements harmonization process, consolidating the original 166 requirements down to 63 core requirements, while archiving the original entries. Also, in searching for areas of perceived duplication, the database reports of requirements and associated projects identified areas of high concentration of research, development, and acquisition activity. The points of contact information stored in the database proved useful in linking people working in similar or related areas.

It is envisioned that the database will become an integral part of the UXO Center of Excellence. The database can continue to aid in the coordination process of storing and sorting requirements, project, technology, and point of contact records and manage the relationships between those records. The database can be used as a tool to increase awareness of efforts in UXO clearance technology research, development, and acquisition.

Figure H.1 UXO Technology Management Database: Main Menu

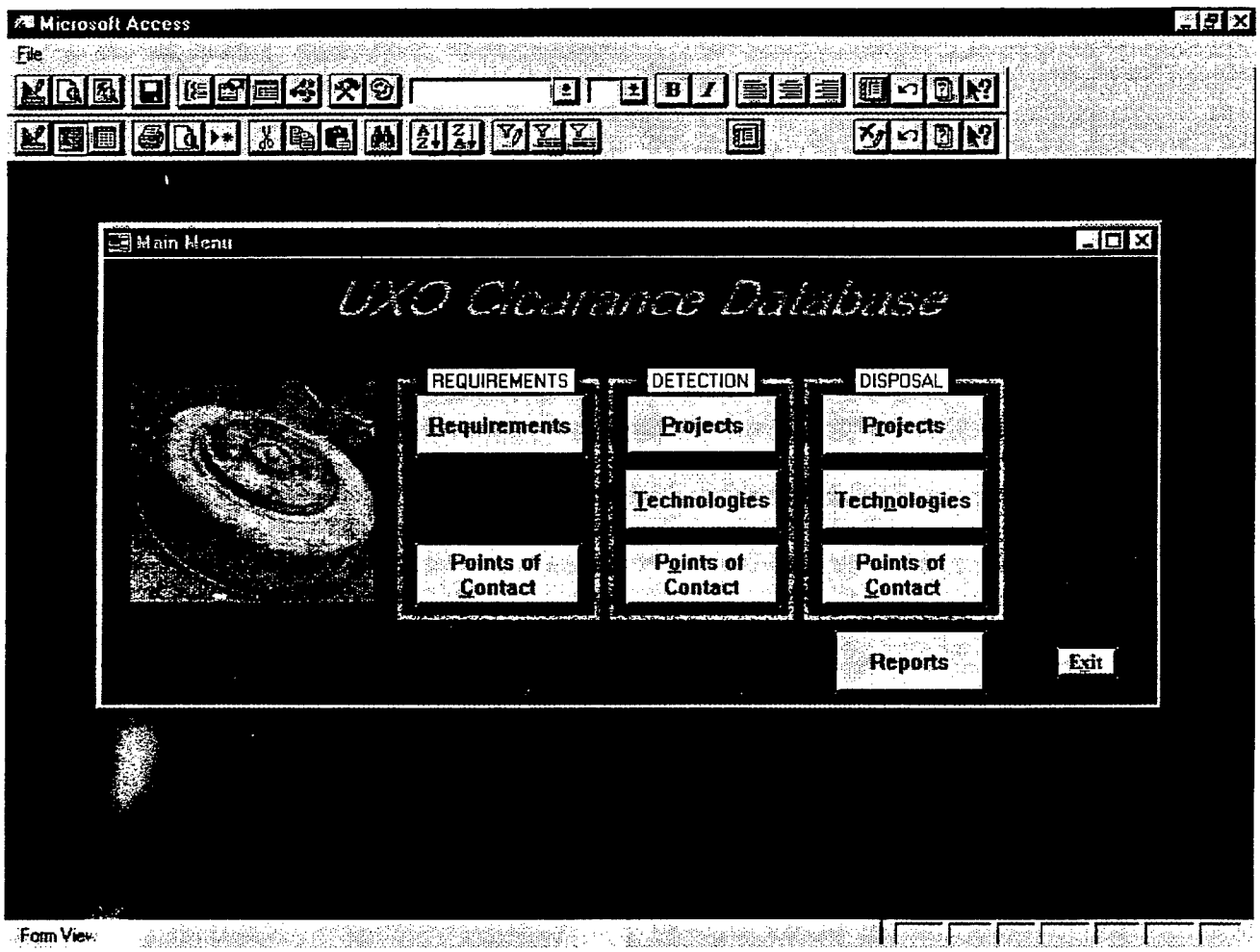


Figure H.2 UXO Technology Management Database: Menu of Reports

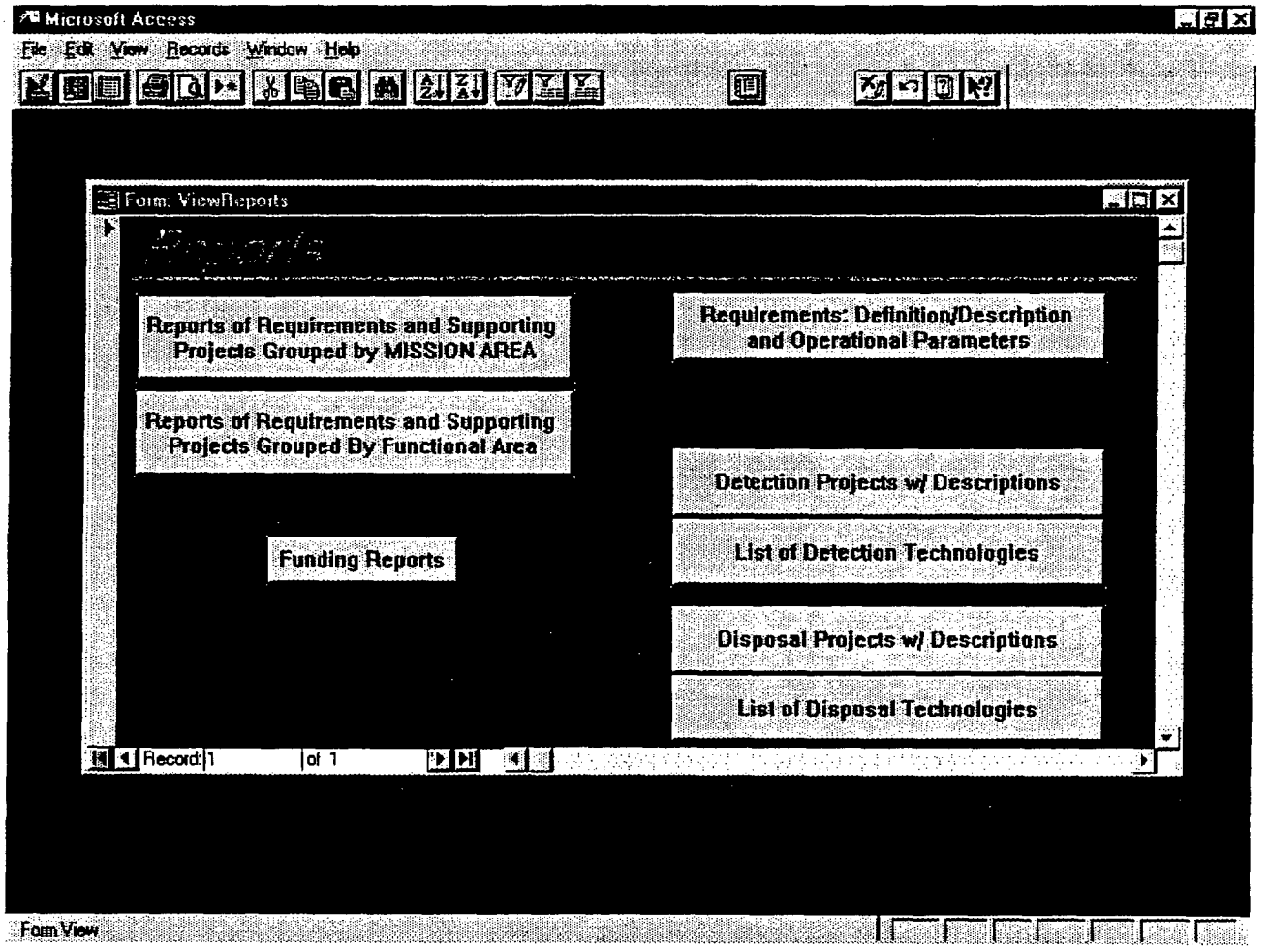
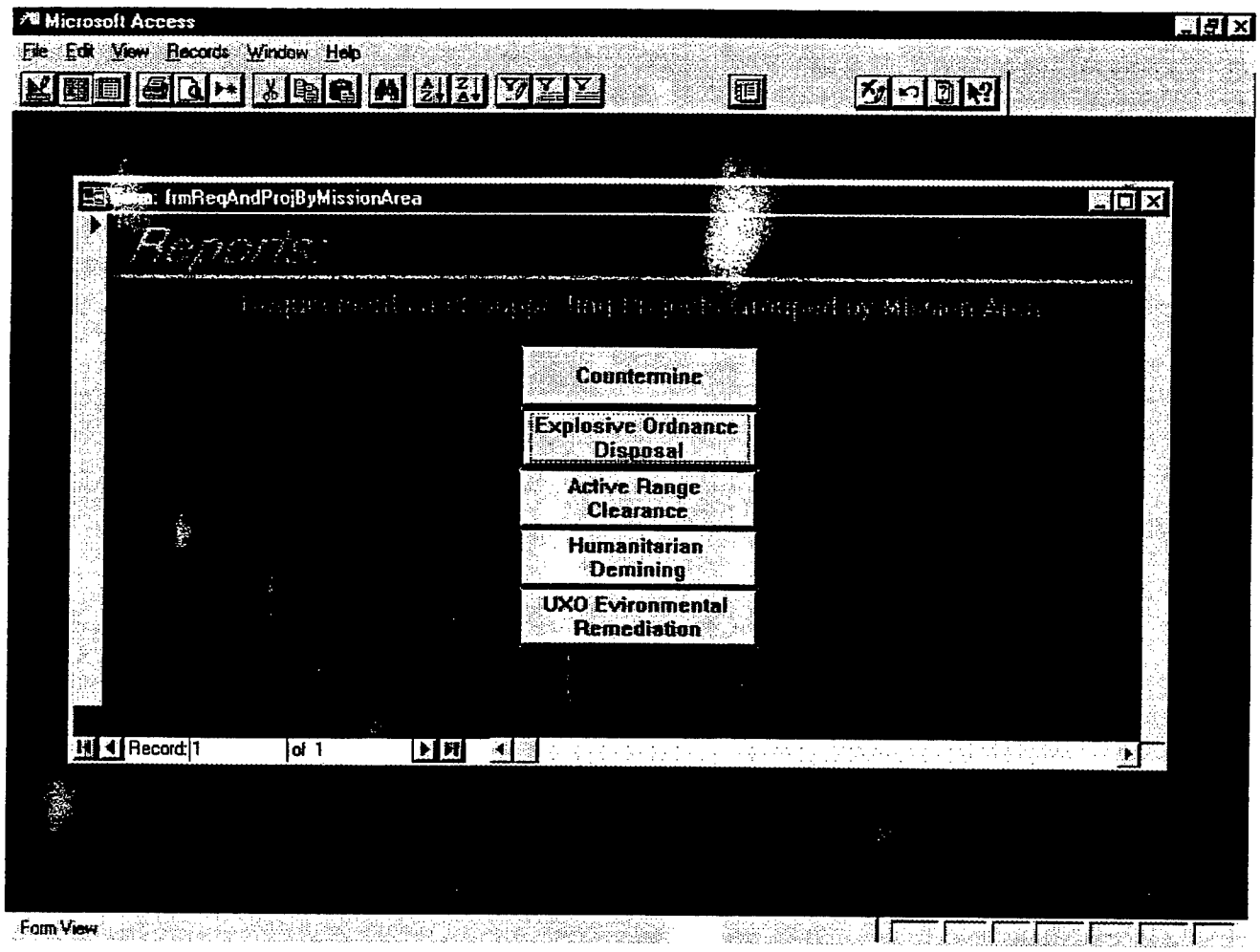


Figure H.3 UXO Technology Management Database: Sub-Menu of Reports: Reports of Requirements and Associated Projects Grouped by Mission Area



APPENDIX I

Abbreviations and Acronyms

ABCA	America Britain Canada Australia
ABMS	Assault Breach Marking System
AEODPS	Advanced EOD Publication Series
AFOL	Advanced Ferrous Ordnance Detector
AP	Anti-Personnel
APL	Anti-Personnel Landmines
APOBS	Anti-Personnel Obstacle Breaching System
ARC	Active Range Clearance
ARO	Army Research Office
ARS	Advanced Radiographic System
ASTAMIDS	Airborne Standoff Minefield Detection System
AT	Anti-Tank
ATD	Advanced Technology Demonstration
ATR	Automatic Target Recognition
Auto RECORM	Autonomous Remote Controlled Ordnance Reconnaissance Monitor
BAA	Broad Agency Announcement
BASIC	Body Armor Set, Individual Countermine
BES	Budget Estimate Submission
BIP	Blow-in-Place
BPA	Berm Processing Assembly
BRAC	Base Realignment and Closure Commission
BUGS	Basic UXO Gathering System
CBU	Cluster Bomb Unit
CECOM/NVESD	U.S. Army Communication and Electronics Command, Night Vision and Electronic Sensors Directorate
CLAMS	Cleared Lane Marking System
CM	Countermine
COBRA	Coastal Battlefield and Reconnaissance Analysis
CONUS	Continental United States
COTS	Commercial Off the Shelf
CPK	Crew Protection Kit

DARPA	Defense Advanced Research Project Agency
DEA	Data Exchange Agreement
DoD	Department of Defense
DOE	Department of Energy
DOJ	Department of Justice
DOS	Department of State
DOT	Department of Transportation
DSB	Defense Science Board
DTO	Defense Technology Objective
EMD	Engineering and Manufacturing Development
EOD	Explosive Ordnance Disposal
EOD/LIC	Explosive Ordnance Disposal/Low Intensity Conflict
ESAF	Electronic Safe and Arm
ESMB	Explosive Standoff Mine Breacher
ESTCP	Environmental Security Technology Certification Program
FAR	False Alarm Rate
FCT	Foreign Comparative Test
FLHR	Forward Looking, Hand-held Ground Penetrating Radar
FUDs	Formerly Used Defense Sites
FUE	First Unit Equipped
GAO	General Accounting Office
GFE	Government Furnished Equipment
GIS	Geographic Information System
GPR	Ground Penetrating Radar
GPS	Global Positioning System
GSTAMIDS	Ground Standoff Minefield Detection System
HEMMS	Hand Emplaced Minefield Marking System
HEMMT	Heavy Expanded Mobility Tactical Truck
HD	Humanitarian Demining
HLONS	HMMWV Laser Ordnance Neutralization System
HNSC	House Committee on National Security
HSATMIDS	Hand-held Standoff Minefield Detection System
HMMWV	High Mobility Multipurpose Wheeled Vehicle
IDLH	Imminent Danger to Life and Health
IEDs	Improvised Explosive Devices
IPT	Initial Production Test
IR	Infrared
IRTI	Infrared Thermal Imager
IVVMD	Interim Vehicle Mounted Mine Detector

JPG	Jefferson Proving Ground
JRP	Joint Robotics Program
JUXOCO	Joint UXO Coordination Office
LADAR	Laser Radar
LAMS	Lightweight, Airborne Multi-Spectral Countermine Detection System
LEXFOAM	Liquid Explosive Foam
LIDDS	Lightweight Disposable Disrupter System
LGH	Launched Grapnel Hook
ManPODS	Man Portable Ordnance Detection System
MCD	Main Charge Disrupter
MH/K	Mine Hunter/Killer
MEMS	Micro Electro-Mechanical Systems
MICLIC	Mine Clearing Line Charge
MIDAP	Minefield Detection Algorithm Processor
MIR	Micropower Impulse Radar
MODS	Mobile Ordnance Disruption System
MOU	Memorandum of Understanding
MRV	Mine Resistant Vehicle
MURI	Multi-University Research Initiative
MTADS	Multi-Sensor Towed Array Detection System
NATO	North Atlantic Treaty Organization
NAVEODTECHDIV	Navy EOD Technology Division
NDI	Non-Developmental Items
NGO	Non-government Organization
NVESD	Night Vision and Electronic Sensors Directorate
OB/OD	Open Burn/Open Detonation
OCONUS	Outside Continental United States
OMB	Office of Management and Budget
OPTEMPO	Operational Tempo
OSD	Office of the Secretary of Defense
PM-MCD	Project Manager, Mines, Countermines, and Demolition
PM-ES	Project Manager, Engineer Systems
PMS-EOD	Project Manager, Explosive Ordnance Disposal
POM	Program Objective Memorandum
PROC	Procurement
PUCA	Pick-Up-And-Carry-Away

RCT	Remote Controlled Transporter
RDT&E	Research, Development Test and Evaluation
RDX	Research Development Explosive
RECORM	Remote Controlled Reconnaissance Monitor
RONS	Remote Ordnance Neutralization System
RSP	Render Safe Procedures
SERDP	Strategic Environmental Research and Render Safe Procedures Development Program
SLR	Side Looking Radar
SMCV	Surface Munition Clearance Vehicle
SMUD	Small Arms Munitions Disrupter
SOCS	Subsurface Ordnance Characterization System
SO/LIC	Special Operations and Low Intensity Conflict
SQUID	Superconducting Quantum Interference Device
TARA	Technology Area Review and Assessment
TCV	Total Containment Vessel
TDEM	Time Domain Electro-Magnetic
TNA	Thermal Neutron Activation
TODS	Tele-operated Ordnance Disposal System
TTCP	The Technical Cooperative Program
UV	Ultraviolet
UXO	Unexploded Ordnance
UER	UXO Environmental Remediation
VEHMASID	Vehicle Magnetic Signature Duplicator
VMMD	Vehicle Mounted Mine Detector